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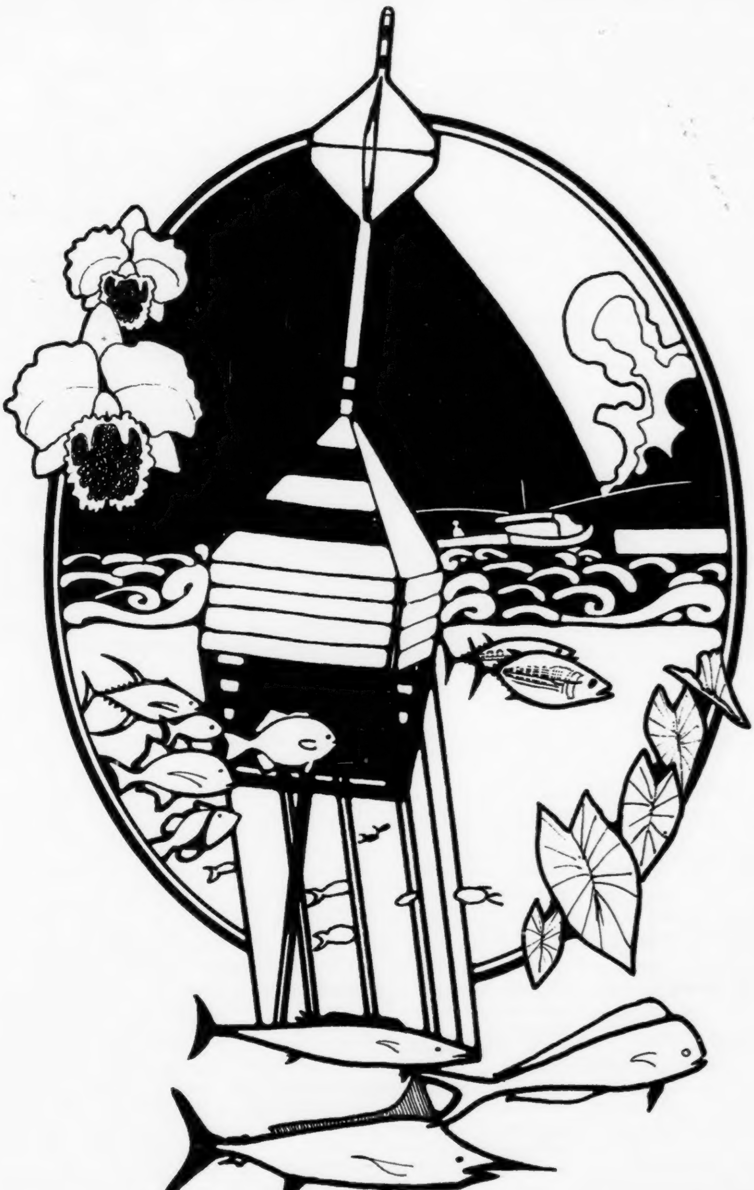

Marine Fisheries REVIEW

On the cover: Anchored fish aggregating devices, growing in use, are discussed in the article beginning on page 1. Illustration by Harold L. Spiess.

Articles — *September 1981, 43(9)*

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Anchored Fish Aggregating Devices in Hawaiian Waters

WALTER M. MATSUMOTO, THOMAS K. KAZAMA, and DONALD C. AASTED

ABSTRACT—Fish aggregating devices (FAD's) made of 55-gallon oil drums and wooden rafts were moored in Hawaiian waters off the islands of Oahu, Lanai, and Hawaii from May 1977 through July 1979. The FAD's successfully attracted numerous pelagic fishes, including large schools of skipjack and small yellowfin tunas. Commercial tuna pole-and-line boats benefited greatly by taking large catches of tunas from around the FAD's. Fishing around the FAD's resulted in reduced fuel and baitfish expenses. Trolling boats also benefited as they experienced a reduction in the number of zero-catch days. The success of the FAD experiment encouraged the State of Hawaii to implement its own FAD system involving 26 fish aggregating devices around seven major islands.

Introduction

Tunas have long been known to aggregate around floating objects such as logs, masses of drifting seaweed, debris, and other flotsam. Both Japanese and American fishermen have utilized this knowledge and routinely seek such objects while fishing for skipjack tuna, *Katsuwonus pelamis*, and yellowfin tuna, *Thunnus albacares*, in the eastern and western Pacific (Uda, 1933; Kimura, 1954; McNeely, 1961; Inoue et al., 1963, 1968).

In recent years, the Japanese began seining for skipjack and small yellowfin tunas in the western equatorial Pacific. The Pacific Tuna Development Foundation (PTDF) also began similar operations in the western Pacific with chartered American seiners (PTDF, 1979). In both operations the success of seining for tunas depended largely upon schools associated with drifting logs. The ratio of successful sets in the PTDF operations was well over 4:1 in favor of sets made around drifting logs as compared with sets made on schools independent of logs.

While the value of drifting logs to successful seining has been well demonstrated by these questions, such logs, which abound in the western equatorial Pacific, especially in waters north of Papua New Guinea, are only seldom found around islands in the central Pacific. Moreover, whenever an occasional log is encountered in the latter areas, it is available to the local fishermen only for a short time before it drifts off beyond the range of their boats. Thus, to benefit from this type of fishing in areas where drifting logs are scarce, it may be necessary for man to turn to anchored devices.

This has been done in the Philippines in recent years where purse seining for tunas around large bamboo rafts (7 × 36 feet) anchored in very deep waters (2,000-3,000 fathoms) has developed into a sizable tuna fishery (Matsumoto[1]). The anchored rafts, numbering in the hundreds and spaced 4-8 miles apart, have successfully attracted large quantities of tunas and enabled the seiners to operate continuously for 6 months or more at a time. The success of this fishery has been mainly due to the availability of vast areas of protected waters in the Philippines where the seas are exceptionally calm.

The Honolulu Laboratory of the National Marine Fisheries Service (NMFS) Southwest Fisheries Center and the PTDF embarked on a joint project to test anchored fish aggregating devices in Hawaiian waters in May 1977. The project was funded largely by PTDF with additional support from NMFS. This report covers the procedures and results of the project.

Objectives

The primary objectives of the project were to: 1) Develop and test anchored fish aggregating devices (hereafter called buoys) in open ocean areas and 2) determine their effect upon the skipjack tuna pole-and-line fishery in Hawaii. Secondary objectives were to determine the effects of buoy placement relative to distance from land, depth, and bottom topography.

Procedure

Buoy Construction

Two types of buoys were used in the experiment. The first type (Fig. 1, 2) consisted of a buoy made of two 55-gallon steel oil drums filled with polyurethane foam and held together in a frame of 3- × 3-inch angle iron. The frame was extended below to form V's at the front and rear and wooden slats were bolted to the V sections to form a haven for small fish. This also provided additional stability to the buoy. A pyramid made of angle iron and plywood

[1]Matsumoto, W. M. Seine fishing around payaos in the Philippines. Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812. Manuscr. in prep.

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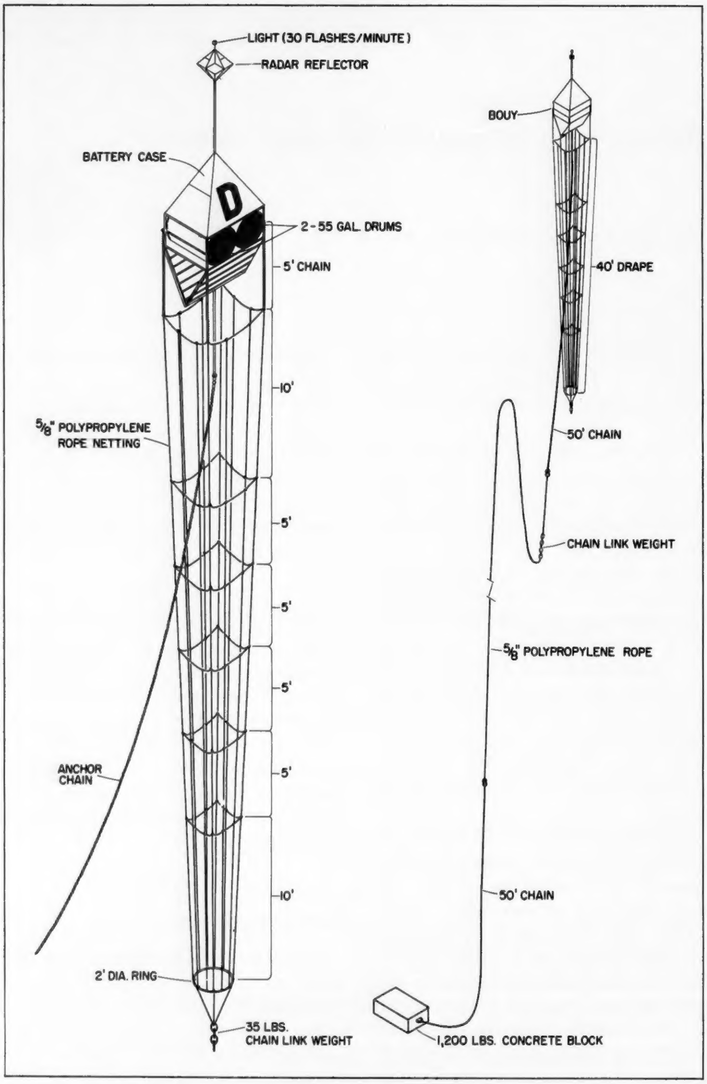

Figure 1.—Fish aggregating device, buoy type.

Figure 2.—Fish aggregating device in place off Oahu, Hawaii.

was welded over the drums and a radar reflector and a navigational warning light were mounted above the pyramid. Details of the buoy and radar reflector are shown in Figures 3 and 4.

A battery compartment was built into the upper half of the pyramid, which was painted in alternate orange and white horizontal bands and marked A, B, C, etc. The light, which was equipped with a photosensor and flashed 32 times per minute, was visible at 0.75 mile. It was energized by three 6-V lantern batteries encased in a length of 3-inch polyvinyl chloride (PVC) pipe. The battery pack provided energy for up to 5 months.

Initially, a 1 × 3 × 30-foot raft made of 1½-inch PVC pipes bolted onto metal frames with floats at both ends was tethered to the buoy. Six to eight coconut palm fronds attached to a 50-foot cable were suspended from the end of the raft. The palm fronds were soon found to be too fragile to withstand the prevailing wave action, and the raft itself was prone to excessive damage because it collided with the buoy in rough seas. Consequently, both raft and fronds were removed from the buoy and a drape made of polypropylene rope was suspended directly from the buoy (Fig. 1).

The second type was a raft (Fig. 5), 4 × 12 feet, made of 2- × 6-inch wooden planks on top and bottom and bolted to four 4- × 4-inch crosspieces. The space between the top and bottom layers of planks was filled with polyurethane foam. A superstructure identical with that used on the buoy was mounted on the raft and a drape, made of 1-inch mesh nylon netting, was hung from the rear third of the raft. These rafts were used only off Kona, Hawaii.

Anchor and Mooring Method

The anchor consisted of a 1,200-pound block of concrete, reinforced with steel bars, and fitted with a ¾-inch galvanized eyebolt at one end.

The anchor line consisted of 50-foot

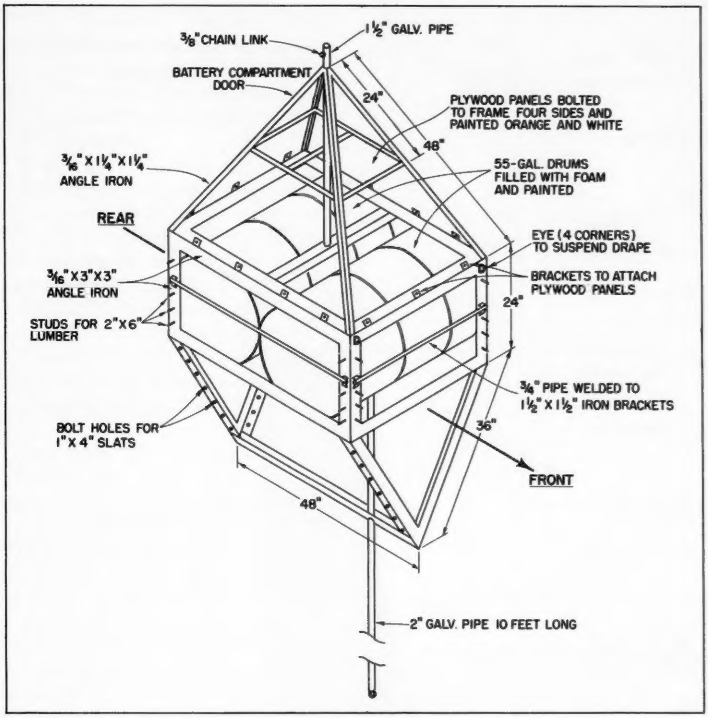

Figure 3.—Details of two-drum buoys.

lengths of ½-inch galvanized chain at the top and bottom and a main section of ⅝-inch twisted polypropylene rope. The scope or ratio of anchor line to depth was between 1.65:1 and 1.80:1. Such a large scope, together with the positive buoyancy of the polypropylene rope, caused large sections of anchor line to float at the surface periodically during changes in the tidal current and thereby posed a hazard to navigation. To correct this, a chain link weight was added to the upper one-fourth to one-third of the anchor line to keep the excess line submerged at all times. The position and size of the weight varied from one buoy to the next, depending upon the length of the anchor line and the depth of the anchoring site. The weight was linked into the line to prevent it from chafing the anchor line.

The simplest method was used in mooring the buoys. The buoy was first set on the water at the selected site, the anchor line was payed out as the vessel moved slowly in a circular path around the buoy, and the anchor was released in a free fall to the bottom.

Location of Buoys

Four buoys were initially moored off Oahu and Lanai (Fig. 6) on 9 and 10 May 1977. Buoy A was placed 16 miles south-southwest of Kewalo Basin (lat. 12°04′N, long. 158°00.4′W), Oahu, at a depth of 308 fathoms; buoy B was placed 18 miles southeast of Kewalo Basin and 1 mile off Penguin Bank (lat. 21°00.5′N, long. 157°43.7′W) at a depth of 242 fathoms; buoy C was moored 27 miles south-southeast of Kewalo Basin and 1.1 miles off the tip of Penguin Bank (lat. 20°51′N, long. 157°45′W) at a depth of 246 fathoms; and buoy D was moored 10.5 miles southwest of Lanai (lat. 19°20′N, long. 157°10′W) at a depth of 345 fathoms. Buoys A and D were situated within 2 miles of the 500- to 1,000-fathom slope, whereas buoys B and C were 14 and 6 miles, respectively, from the slope.

The first three buoy sites were fully exposed to the northeast trades, which predominated in all seasons, and to occasional south winds, often accompanied by storms. The buoys were thus buffeted by winds from 15 to 25 knots, often approaching gale force. The seas were generally from 4 to 12 feet but exceeded 20 feet during storms. Site D was relatively calmer, with seas generally ranging from 2 to 4 feet. During stormy periods, however, the seas ranged as high as 10 feet.

Subsequently, on 22 March 1978, two raft-type devices were moored off Kona, Hawaii, in relatively calm waters. The first, F, was placed 4.5 miles west of Kaiwi Point at a depth of 1,250 fathoms and the second, G, was placed 6 miles offshore and 8 miles north-northwest of Keahole Point at a depth of 220 fathoms. The latter was situated 3.5 miles shoreward from the 1,000-fathom slope. Both of these sites were in proven fishing areas for tunas and billfishes.

Monitoring Buoys and Catches

Monitoring and maintenance of the buoys off Oahu and Lanai were scheduled on a monthly basis, with additional visits at the height of the skipjack tuna fishing season. All visits could not be made as planned, however, due to prolonged periods of rough sea conditions.

On all monitoring trips, troll fishing was done at each buoy site and on runs between buoys. Sightings of bird flocks, fish schools, and scattered birds were recorded and the areas immediately around the buoys were scanned with a depth recorder to detect subsurface fish schools.

Fish catch data from commercial tuna pole-and-line boats visiting the buoys were obtained through catch forms supplied to each boat and from interviews with boat operators. Catch data from commercial and recreational trolling boats were obtained from interviews once or twice each week and were limited to boats based at Kewalo Basin,

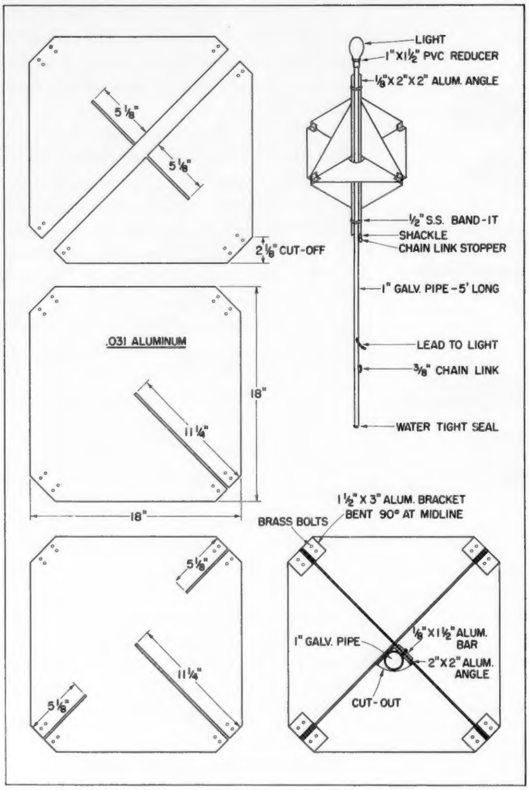

Figure 4.—Details of radar reflector.

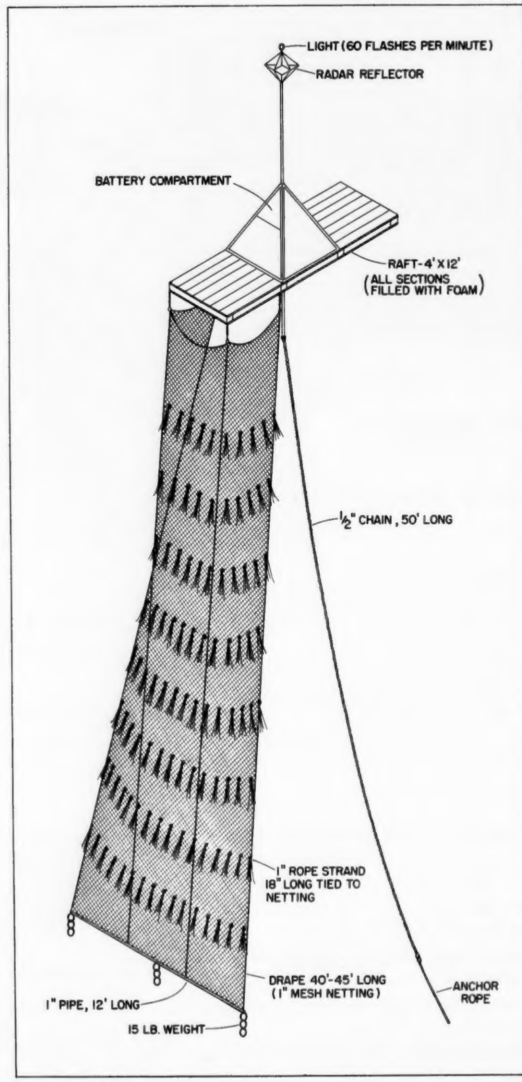

Figure 5.—Fish aggregating device, raft type.

since it was not possible to monitor the numerous trailer boats launched from scattered points on the island. Fish catch forms also were distributed to boats fishing out of Kona and Maui. Underwater observations were made at buoys D and F, both located in calm water.

Results

Buoy Performance

The buoys performed as expected in attracting and holding marketable fish species. The dolphin, *Coryphaena hippurus*, and wahoo, *Acanthocybium solanderi,* were among the first to be caught by trolling around the buoys. These fish appeared from 1 to 3 weeks after the buoys had been anchored. Both species generally appeared in small numbers but sizable catches of 10-20 dolphin were reported on 14 occasions and 20-30 fish on 4 occasions. The two largest single-day catches of this species were 32 and 41 fish.

Schools of tunas, small yellowfin, skipjack, and kawakawa, *Euthynnus affinis*, generally appeared from 2 to 5 weeks after the buoys had been deployed. The early arrivals were small fish weighing

from 1 to 4 pounds. These were joined later by larger fish as the tuna aggregations increased around the buoys. Other fish of the families Carangidae, Balistidae, and Kyphosidae often appeared well before the tunas.

As the aggregations of fish built up around the buoys, so did the number of fishing boats. These included commercial bait boats, chartered (sport fishing) and commercial trollers, and trailer boats of assorted sizes. Buoy A attracted as many as 30 boats on a given day, all fishing simultaneously around the buoy and up to a distance of 3 miles. In the calmer waters off Kona, F and G buoys attracted 50 or more boats on a given day.

Buoy losses were experienced at all sites. The four buoys (A-D), initially deployed on 9 and 10 May 1977, broke free in July after 7-10 weeks because of incompatible fittings used in the anchor line. Subsequently, two more buoys were lost at sites A and B and one more each at sites C and D from other causes. At site A, the second buoy was lost after 16.5 months as a result of a storm and the third buoy was lost after 4.5 months, due to cable grip slippage. On this buoy, 100 feet of ⅜-inch cable, secured by three safety cable grips at each end, was used at the top of the anchor line, instead of the usual length of chain. At site B, the second buoy was lost after 3 months as a result of line chafing. The buoy was inadvertently anchored too close to Penguin Bank, and the anchor rope failed to clear the top of the ledge as the buoy swung over the bank during tidal changes. The third buoy was lost after 16.75 months when a shackle pin was lost. At site C, the second buoy was lost after 19.75 months due to undetermined causes, and at site D, the second buoy was lost after 16.5 months after it had been dragged by currents to a shallow ledge where the anchor rope eventually chafed on the bottom. Despite these losses, the buoys at all sites remained in position long enough to demonstrate their effectiveness in attracting and holding fish schools.

The buoy design was adequate at all sites, except D, where unforeseen strong currents occurred twice during the testing period. On both occasions the current forced the buoy to submerge and caused the anchor to be dragged along the relatively flat, mud and silt bottom.

The buoys off Kona (F and G) were not part of the original buoy project. Consequently, wooden rafts that were available from a prior experiment were used instead of the steel-drum buoys. These rafts remained operative for 10 months before breaking apart during the same series of storms that caused the losses of A and D buoys. The winds off Kona exceeded 40 knots during this storm.

The drapes of fine-mesh netting used on F and G buoys were very effective in attracting fish; however, they also gilled numerous mackerel scad, *Decapterus punctatus* (Fig. 7), and were torn to shreds from sharks feeding on the gilled fish.

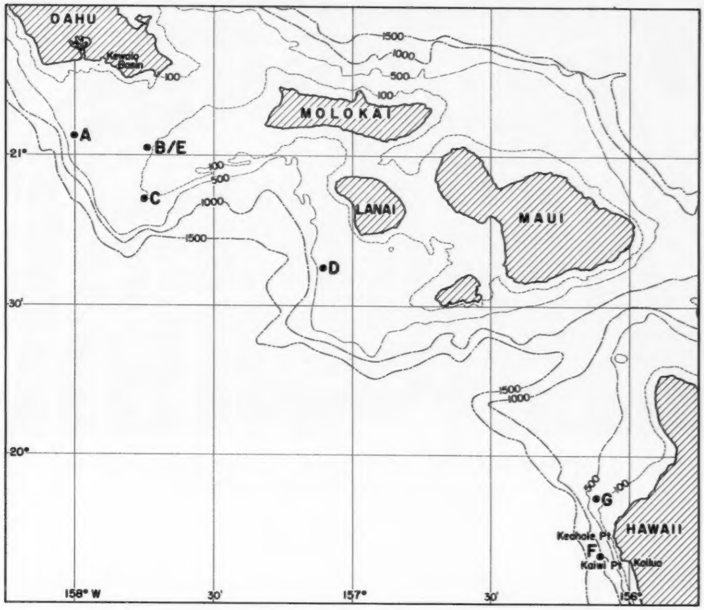

Figure 6.—Fish aggregating devices off Oahu, Lanai, and Hawaii.

Monitoring Trips

Visits to the buoys were interrupted at various times, either because of rough sea conditions or loss of buoys (Table 1). Sixteen visits were made to A, 13 to B, 13 to C, and 10 to D. The catch by trolling on these trips was generally low at all the buoys. The total catch consisted of 29 fish at A (1.8 fish per visit), 11 at B (0.8 fish per visit), 3 at C (0.2 fish per visit), and 7 at D (0.7 fish per visit). The low catch was largely due to fishing by trollers prior to the arrival of the monitoring vessel. Consequently, determination of the presence of fish around the buoys were made from fish and bird flock sightings and fish-finder observations. Fish were present at A and 13 of 16 visits (81.2 percent), at B on 8 of 13 visits (61.5 percent), at C on 6 of 13 visits (46.2 percent), and at D on 9 of 10 visits (90.0 percent). Thus, buoys A and D, because of their locations (see Discussion), were more effective in attracting fish than B and C.

To determine the effectiveness of the buoys statistically, controlled fishing by trolling was done within 0.5 mile and at distances of 3 to 5 miles from the buoys

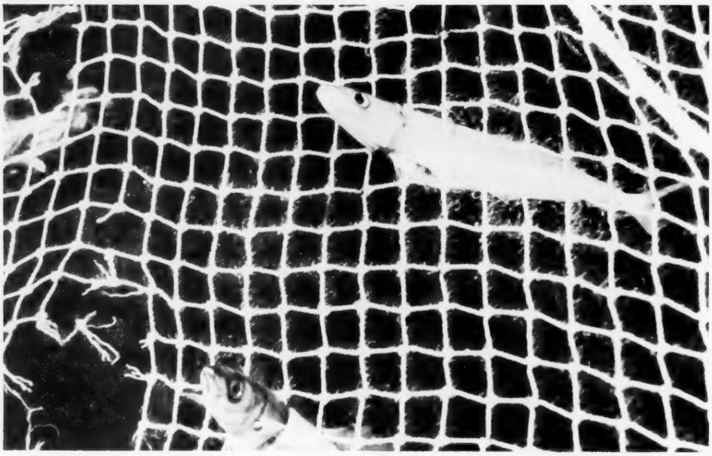

Figure 7.—Mackerel scad gilled on netting hung from fish aggregating device. Torn sections caused by shark attacks on gilled fish.

by a commercial trolling boat and vessels used in monitoring the buoys. Because of differences in fishing duration and in number of lines fished by different vessels, catch-per-line-hour was used in comparing the effect of the buoys in the two areas. Sixteen pairs of observations were obtained in March, April, and August 1978. Of these, fish were caught within 0.5 mile of the buoy on nine occasions, between 3 and 5 miles on one occasion, and in both areas on one occasion. No fish was caught in both areas on five occasions. There were 10 positive differences in the catch rates in favor of the buoy area, 1 negative difference, and 5 with no difference.

The randomized test for matched pairs (Siegel, 1956) indicated that catch rates within 0.5 mile of the buoys were significantly greater ($P = 0.00097$, one-tailed) than in areas 3 to 5 miles away. The test, thus, indicated that the buoys were successful in aggregating fish.

Pole-and-Line Fishing

The buoys were first deployed in May, at the beginning of the skipjack tuna fishing season. The anticipated visits to the buoys by pole-and-line boats during the fishing season did not occur because of the unexpected loss of all four buoys in July and because the buoys could not be reinstalled before the end of the fishing season. All four buoys were reinstalled between August and October, and visits by pole-and-line boats began in December. Initially, the few boats that fished around the buoys were reluctant to report their visits and catches because they did not want other boats to visit the buoys also. The reporting of visits and catches improved with time, however, as the effectiveness of the buoys became common knowledge throughout the fishing fleet.

Several of the smaller bait boats visited the buoys more often than the others. These boats usually left port well before daybreak in order to be at the buoy site by sunrise. They began fishing at the buoys at daybreak and pursued the schools as the latter departed from the immediate area of the buoys. As fishing slacked off, the boats departed the area to seek schools of larger fish. Depending on the day's catch, these boats visited the buoys again in late afternoon before returning to port. Occasionally when fishing around the buoys was exceptionally good, these boats returned to port well before noon with catches of 10,000 pounds, or more.

During 1978, the number of known visits increased from a low of 9 in January to 80 in May (Table 2), representing 5.6 and 46.8 percent, respectively, of the total monthly fishing trips made by the fleet of 12 pole-and-line boats. The ratio of visits to total trips peaked in April, decreased sharply in June, and remained low throughout the remainder of the year. This was reflected in the total monthly catches around the buoys. The sharp increase in catch at the buoys in April corresponded with the start of the fishing season when season fish (medium and large skipjack tuna) entered the fishery. The significant drop in the monthly catches around the buoys in June, July, and August was due to reduced visits to the buoys as a result of the presence of these season fish in areas away from the buoys. Because these fish commanded two and three times more per unit price of small fish which predominated in the catch around the buoys, they drew the boats away from the buoy sites.

The high catches of 424,897 pounds in April and 431,129 pounds in May represented 58.4 and 43.3 percent of the respective total cannery landings. During this period, there were 23 catches of over 10,000 pounds, 2 catches of over 20,000 pounds, and 2 catches of over 30,000 pounds. (One boat reported catches of nearly 60,000 pounds in a 3-day period.) The average catch per visit was 7,326 pounds in April and 5,389 pounds in May.

Fish species taken by pole-and-line boats at the buoys (Table 3) included skipjack tuna (89.7 percent), yellowfin tuna (9.3 percent), kawakawa (0.6 percent), and dolphin (0.3 percent). The skipjack tuna ranged in size from 2 to 12 pounds, with occasional catches of large fish above 20 pounds. Small yellowfin tuna and kawakawa ranged in size from 2 to 12 pounds and dolphin from 10 to 30 pounds. Skipjack tuna were taken at all four sites, but mostly at A and D. The single recorded visit to B consisted of a catch from one skipjack tuna school. Yellowfin tuna were taken mostly at D, with a fair amount at A, and a small amount at C. Kawakawa were taken at these three sites also, but the bulk of the catches were made at C.

The pattern of visits and catches in 1979 did not follow that of the previous

Table 1.—Visits and observations at monitored buoys.

	A							B						
Date	Time	Line hours trolled	Catch	Catch per line hour	Fish seen[1]	Bird flock (No. birds)	Fish finder[2]	Time	Line hours trolled	Catch	Catch per line hour	Fish seen[1]	Bird flock (No. birds)	Fish finder[2]
1977														
May 26	1600	0.50	0	0.00	1	0	—	0845	0.33	1	3.03	0	20	—
June 14-15	0828	1.42	0	0.00	3	0	F-15	1103	1.42	1	0.72	3	0	0
July 2-3				Buoy lost 1 July				1130	1.50	1	0.67	0	0	F-20
July 17								1025	2.25	0	0.00	1	0	0
Aug.				Replaced 8 Aug.							Buoy lost 20 July			
Sept. 12	1015	0.67	0	0.00	1	250	S-15, 25				Replaced 27 Sept.			
Oct. 19	1026	0.60	0	0.00	0	0	F-16	1256	0.27	0	0.00	0	0	—
Nov. 19-20	1235	1.50	0	0.00	1	15	0	1535	0.95	0	0.00	0	0	0
Dec. 15-16	1325	1.15	0	0.00	0	0	0				Buoy lost 2 Dec.			
1978														
Jan. 23	0926	1.00	0	0.00	0	0	0							
Feb.				No visit[3]							Buoy lost 2 Dec.			
Mar. 21-23	0738	1.15	1	0.87	0	0	—				Replaced 20 March			
Apr. 13-14	0700	4.00	6	1.50	TS	1,000	—	0835	1.67	0	0.00	0	15	0
May 30-31				No visit				0925	0.67	0	0.00	2	0	—
June 1	0735	1.33	0	0.00	1	150	—				No visit			
July				No visit[3]							No visit[3]			
Aug. 17-18	1030	2.50	0	0.00	0	0	—	1010	4.58	7	1.53	0	25	—
Sept. 20-21	0825	0.75	0	0.00	TS	10	—	0950	0.75	0	0.00	1	0	—
Oct.				No visit[3]							No visit[3]			
Nov.				No visit[3]							No visit[3]			
Dec.				Buoy lost 26 Dec.							No visit[3]			
1979														
Jan.				Buoy lost							No visit[3]			
Feb.				Buoy lost							No visit[3]			
Mar. 6				Replaced 31 Mar.				1005	0.67	0	0.00	0	0	—
Apr. 11				No visit				0752	0.50	0	0.00	0	0	—
May				No visit							No visit			
June 1	0750	2.33	2	0.86	TS	300	S-15				No visit			
June 29	0700	3.50	6	1.71	TS	200	0				No visit			
July 10	0615	2.67	13	4.87	0	0	0				No visit			
July 10				No visit				0805	5.33	1	0.19	0	0	0
July 31	1700	8.00	1	0.13	0	20	—				No visit			
Aug.				Buoy lost 8 Aug (terminated)							Buoy lost 8 Aug. (terminated)			

	C							D						
Date	Time	Line hours trolled	Catch	Catch per line hour	Fish seen[1]	Bird flock (No. birds)	Fish finder[2]	Time	Line hours trolled	Catch	Catch per line hour	Fish seen[1]	Bird flock (No. birds)	Fish finder[2]
1977														
May 26	1100	0.50	0	0.00	4	50	—				No visit			
June 14-15	1304	1.33	0	0.00	1	60	—	0630	1.25	0	0.00	3	0	0
July 2-3	0700	1.40	0	0.00	2	40	0	0815	4.50	6	1.33	18	45	0
July 17	1200	1.25	0	0.00	7	0	0				No visit			
Aug.				Buoy lost 20 July							Buoy lost 20 July			
Sept. 12														
Oct. 19				Replaced 19 Oct.							Replaced 19 Oct.			
Nov. 19-20	0700	0.85	0	0.00	0	0	0	1330	1.10	0	0.00	6	0	S-10
Dec. 15-16	1450	1.00	0	0.00	0	0	0	0640	1.70	0	0.00	TS	100	—
1978														
Jan. 23	1230	0.93	0	0.00	0	0	0	1750	0.67	0	0.00	0	0	0
Feb.				No visit[3]							No visit[3]			
Mar. 21-23	0612	1.40	1	0.71	0	0	—	1537	0.65	0	0.00	10	75	—
Apr. 13-14	1810	1.25	0	0.00	0	0	0	1341	2.00	0	0.00	TS	25	—
May 30-31	1043	0.80	0	0.00	0	0	—	1445	2.33	0	0.00	TS	50	—
June 1				No visit							No visit			
July				No visit[3]							No visit[3]			
Aug. 17-18	0735	2.50	1	0.40	0	0	—	1715	6.25	1	0.16	0	100	—
Sept. 20-21	1210	1.25	0	0.00	0	0	—	1652	1.50	0	0.00	TS	30	—
Oct.				No visit[3]							No visit[3]			
Nov.				No visit[3]							No visit[3]			
Dec.				No visit[3]							No visit[3]			
1979														
Jan.				No visit[3]							No visit[3]			
Feb.				No visit[3]							Buoy lost 26 Feb. (terminated)			
Mar. 6	1145	0.75	0	0.00	0	0	—	—	—	—	—	—	—	—
Apr. 11	0938	0.33	1	3.03	0	0	—	—	—	—	—	—	—	—
May				No visit				—	—	—	—	—	—	—
June 1				Buoy lost 10 June (terminated)										
June 29	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[1]TS=tuna school.
[2]Scattered fish (F) or school (S) at stated depth in fathoms.
[3]No visits to buoys due to rough seas.

Table 2.—Monthly catches (in pounds) of tuna by pole-and-line boats during fish aggregating device experiment.

Year/ month	Buoy A Catch	A Visit	B Catch	B Visit	C Catch	C Visit	D Catch	D Visit	Totals Catch	Totals Visit	Catch per visit	Landings by fleet	Trips by fleet	Catch per trip	Percent buoy visit	Percent buoy catch
1977																
Dec.	10,000	1	–	–	–	–	25,200	2	35,200	3	11,733.3	226,622	126	1,798.6	2.4	15.5
1978																
Jan.	9,000	2	–	–	18,600	3	13,938	4	41,538	9	4,615.3	410,210	160	2,563.8	5.6	10.1
Feb.	7,849	7	–	–	1,396	2	40,085	20	49,330	29	1,701.0	143,522	111	1,292.9	26.1	34.4
Mar.	9,718	6	–	–	–	–	22,872	14	32,590	20	1,629.5	142,646	69	2,067.3	29.0	22.8
Apr.	86,738	14	5,110	1	88,734	9	224,315	34	424,897	58	7,325.8	727,933	109	6,678.3	53.2	58.4
May	208,288	48	–	–	–	–	222,841	32	431,129	80	5,389.1	996,312	171	5,826.4	46.8	43.2
June	31,503	7	–	–	–	–	–	–	31,503	7	4,500.4	909,456	183	4,969.7	3.8	3.5
July	28,109	9	–	–	–	–	–	–	28,109	9	3,123.2	869,491	166	5,237.9	5.4	3.2
Aug.	–	–	–	–	–	–	23,170	5	23,170	5	4,634.0	571,981	125	4,575.8	4.0	4.1
Sept.	–	–	–	–	–	–	30,725	9	30,725	9	3,413.9	251,363	80	3,142.0	11.2	12.2
Oct.	–	–	–	–	–	–	22,882	9	22,882	9	2,542.4	341,885	97	3,524.6	9.3	6.7
Nov.	–	–	–	–	–	–	34,162	12	34,162	12	2,846.8	471,969	107	4,410.9	11.2	7.2
Dec.	–	–	–	–	–	–	–	–	–	–	–	218,450	76	2,874.3	–	–
Total	381,205	93	5,110	1	108,730	14	654,990	139	1,150,035	247	4,656.0	6,055,218	1,454	4,164.5	17.0	19.0
1979																
Jan.	Buoy lost		–	–	–	–	–	–	–	–	–	113,050	47	2,405.3	–	–
Feb.			–	–	–	–	–	–	–	–	–	220,540	74	2,980.3	–	–
Mar.			–	–	–	–	Buoy lost		–	–	–	258,607	74	3,494.7	–	–
Apr.	Buoy replaced		–	–	–	–			–	–	–	280,668	109	2,574.9	–	–
May	10,500	5	–	–	–	–			10,500	5	2,100.0	1,045,667	176	5,941.3	2.8	1.0
June	18,841	5	–	–	Buoy lost				18,841	5	3,768.2	827,293	187	4,424.0	2.7	2.3
July	4,200	3	–	–					4,200	3	1,400.0	1,012,239	184	5,501.3	1.6	0.4
Aug.	Buoy lost		Buoy lost						–	–	–	–	–	–	–	–
Total	33,541	13	–	–	–	–	–	–	33,541	13	2,580.1	3,758,064	851	4,416.1	1.5	0.9

Table 3.—Fish species caught (in pounds) by pole-and-line boats around fish aggregating buoys during 1978.

Buoy	Visits	Skipjack tuna Catch	Skipjack tuna Catch per visit	Yellowfin tuna Catch	Yellowfin tuna Catch per visit	Kawakawa Catch	Kawakawa Catch per visit	Dolphin Catch	Dolphin Catch per visit	Total Catch	Total Catch per visit
A	92	357,044	3,880.4	22,682	246.5	1,479	16.0	854	9.3	382,031	4,152.5
B	1	5,110	5,110.0	0	0.0	0	0.0	0	0.0	5,110	5,110.0
C	14	103,037	7,359.8	1,475	105.4	4,218	301.3	0	0.0	108,730	7,766.4
D	139	573,106	4,123.1	80,183	576.9	1,706	12.3	3,034	22.6	658,029	4,734.0
Total	246	1,038,297	4,220.7	104,340	424.1	7,403	30.0	3,888	15.8	1,153,900	4.690.6
Percent of total catch		89.73		9.28		0.64		0.34		99.99	

year for several reasons. First, the presence of large skipjack tuna in the fishery in late fall and winter kept the boats from returning to the buoys in the off-season; second, the December-January period was beset with inclement weather, including several periods of gale-force winds that reduced fishing activity considerably; and third, the loss of buoys A in December 1978 and D in March resulted in the elimination of the two buoys that were most productive of tunas. By the time A was restored in April and the 2-5 weeks necessary for it to become effective had gone by, the regular skipjack tuna fishing season was at hand, and the pole-and-line boats had already turned their attention to large fish away from the buoy areas.

Troll Fishing

Table 4 lists the visits and catches obtained from interviews with trolling boat operators. Only visits to A, B, and C are shown because D, located off Lanai, was beyond the usual 1-day charter range of most trollers based at Kewalo Basin, and because no firm reports were received from boats fishing at this buoy out of Maui and Lanai. Since most of the boats at Kewalo Basin fished irregular schedules and since it was not always possible to interview all boats daily, the number of visits and resultant catches may be greatly understated.

Visits to the buoys generally remained low (8.3 visits per month) during the last half of 1977 due to interruption of fishing caused by buoy losses, rough sea conditions, and poor initial response in reporting by the trollers. Buoy visits increased to 22 visits per month in 1978 and to 44 visits per month in 1979.

During the 26-month period of fishing around the buoys, a total of 2,087 fish, estimated at 29,351 pounds, were taken by trolling boats. The catch rate for the period was 3.44 fish per visit. Although the amount of fish taken was not overwhelming, the buoys, nevertheless, substantially reduced the number of

zero-catch days (interviews with boat operators). From April through July 1978, the period of greatest fish concentration around the buoys, trollers caught 876 fish (estimated weight 11,288 pounds) at a catch rate of 10.55 fish per visit. The concentrations of fish around the buoys were not as great during the same period in 1979. Only 546 fish (estimated weight 10,156 pounds) were caught at a catch rate of 2.92 fish per visit. Both catch and catch rate were affected greatly by reduced fishing at A, the most productive buoy, which was lost in December 1978 and was not replaced until March 1979.

Fishing effort varied at the different buoy sites. Buoy A was visited most often (51.0 percent of all buoy visits) and yielded the most catch (61.5 percent of total buoy catch). Buoy B received 26.4 percent of all visits and yielded 17.7 percent of the total buoy catch, and buoy C recorded 22.6 percent of all visits and yielded 20.8 percent of the catch. Although buoys B and C were not productive of tunas, they were ideally placed to attract dolphin from nearby Penguin Bank. Several boats that preferred trolling for dolphin made regular visits to these sites. The catch rate of dolphin at these two sites averaged 1.87 fish per visit, as compared with 0.70 fish per visit to A.

Twelve species of fish were taken by trollers around the buoys (Table 5). Dolphin comprised the largest group (37.0 percent), followed by yellowfin tuna (25.9 percent), and skipjack tuna (23.0 percent). Of the 772 dolphin taken, nearly 72 percent were from sites B and C in roughly equal amounts; and of the 481 skipjack tuna and 540 yellowfin tuna taken, nearly 88 and 90 percent, respectively, were from site A. Kawakawa represented 9.0 percent of the total catch, with roughly 41 percent taken from A, 36 percent from B, and 23 percent from C. Marlins, *Makaira nigricans* and *Tetrapturus audax*, and

Table 4.—Fish caught by trolling boats based at Kewalo Basin.

	A			B			C			All buoys			
Year/ month	Visit	No. of fish	Wt. (lb)	Visit	No. of fish	Wt. (lb)	Visit	No. of fish	Wt. (lb)	Visit	No. of fish	Wt. (lb)	Catch per visit
1977													
June	8	18	475	3	0	0	4	1	5	15	19	480	1.26
July	—	—	—	5	57	335	1	11	55	6	68	390	11.33
Aug.	2	0	0	—	—	—	—	—	—	2	0	0	0.00
Sept.	2	4	25	—	—	—	—	—	—	2	4	25	2.00
Oct.	12	89	187	7	22	170	1	0	0	20	110	357	5.55
Nov.	2	1	10	2	3	40	1	0	0	5	4	50	0.80
Dec.	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	26	112	697	17	82	545	7	12	60	50	206	1,302	4.12
1978													
Jan.	9	52	327	—	—	—	7	61	439	16	113	766	7.06
Feb.	9	29	216	—	—	—	7	3	26	16	32	242	2.00
March	6	6	272	—	—	—	5	3	50	11	9	322	0.82
April	14	236	2,499	3	5	84	6	38	395	23	279	2,978	12.13
May	19	294	4,083	8	23	363	9	129	992	36	446	5,438	12.39
June	6	35	431	4	32	452	4	33	591	14	100	1,474	7.14
July	7	45	1,340	1	2	16	2	4	42	10	51	1,398	5.10
Aug.	11	14	327	1	7	42	5	17	148	17	38	517	2.24
Sept.	5	17	1,001	1	2	38	—	—	—	6	19	1,039	3.17
Oct.	31	26	953	8	9	152	12	6	105	51	41	1,210	0.80
Nov.	37	33	210	8	10	135	6	6	165	51	49	510	0.96
Dec.	3	10	250	8	1	6	6	2	15	17	13	271	0.76
Total	157	797	11,933	42	91	1,288	69	302	2,944	268	1,190	16,165	4.44
1979													
Jan.	—	—	—	11	18	189	10	21	205	21	39	394	1.85
Feb.	—	—	—	37	69	1,705	15	18	322	52	87	2,027	1.67
March	10	4	51	16	15	180	12	4	48	28	19	228	0.68
April	10	4	51	7	11	144	8	14	171	25	29	366	1.16
May	59	189	2,582	15	36	594	15	61	2,076	89	286	5,252	3.21
June	27	136	1,551	6	22	434	1	3	60	34	161	2,045	4.74
July	30	45	1,315	9	25	257	—	—	—	39	70	1,572	1.79
Total	126	374	5,499	101	196	3,503	61	121	2,882	288	691	11,884	2.40
Total for period	309	1,283	18,129	160	369	5,336	137	435	5,886	606	2,087	29,351	3.44
Percent of all FAD totals	51.0	61.5	61.8	26.4	17.7	18.2	22.6	20.8	20.0				

Table 5.—Species and number of fish caught by trolling boats around fish aggregating buoys, May 1977-July 1979.

	Buoy												
	A			B			C			Total			
Species	Visit	Catch	Catch/ visit	Visit	Catch	Catch/ visit	Visit	Catch	Catch/ visit	Visit	Catch	Catch/ visit	Percent of total
Skipjack tuna	309	423	1.37	160	3	0.02	137	55	0.40	606	481	0.79	23.0
Yellowfin tuna		484	1.57		12	0.08		44	0.32		540	0.89	25.9
Bigeye tuna		11	0.04		0	0.00		10	0.07		21	0.04	1.0
Kawakawa		77	0.25		68	0.42		43	0.31		188	0.31	9.0
Dolphin		217	0.70		275	1.72		280	2.04		772	1.27	37.0
Wahoo		30	0.10		8	0.05		2	0.02		40	0.07	1.9
Blue marlin		15	0.05		3	0.02		1	0.01		19	0.03	0.9
Striped marlin		2	0.01		0	0.00		0	0.00		2	<0.01	0.1
Spearfish		3	0.01		0	0.00		0	0.00		3	<0.01	0.1
Rainbow runner		16	0.05		0	0.00		0	0.00		16	0.03	0.8
Greater amberjack		3	0.01		0	0.00		0	0.00		3	<0.01	0.1
Barracuda		2	0.01		0	0.00		0	0.00		2	<0.01	0.1
Total	309	1,283	4.15	160	369	2.31	137	435	3.18	606	2,087	3.44	

shortbill spearfish, *T. angustirostris*, represented 1.2 percent of the total catch. Nearly all (83.3 percent) were taken at site A. All other fish, including bigeye tuna, *Thunnus obesus*; wahoo; rainbow runner, *Elagatis bipinnulata*; amberjack, *Seriola dumerili*; and barracuda, *Sphyraena argentea*, comprised 3.9 percent of the total catch. All bigeye tuna, except 10, were taken at A. The billfishes were generally taken about 0.5 to 1.5 miles away from the buoy, whereas the skipjack and yellowfin tunas were caught all the way from the buoy up to 3-5 miles away. Most of the other species were taken within 200-300 yards of the buoy.

Occasional reports from Maui indicated heavy fishing activity around buoy D, where individual boat catches of 300-700 pounds of skipjack (8-10 pound size) and yellowfin (30-50 pound size) tunas, and 100 pounds of dolphin per weekend were commonly made in April 1978.

Reports from Kona indicated the success of the buoys placed there. Buoy F, in particular, which had been placed at the edge of an outstanding fishing area, was teeming with skipjack and yellowfin tunas within 5 weeks after deployment. Trollers were able to catch small skipjack tuna for marlin bait in 10-15 minutes, compared with half a day or more before the buoy was in place. During the height of the summer marlin run, many trollers who took advantage of the accessibility of bait-size skipjack tuna at buoy F reported catches of three and four marlin a day. One boat reported catching 11 marlin in a period of 10 consecutive days of fishing, while another caught 20 marlin in 20 days.

Table 6. — Underwater observations of fish at fish aggregating buoys off Lanai and Kona, Hawaii.

Date	Buoy	Locality	Fish observed	Estimated number	Est. fish size (lb)	Depth range (m)
1977						
15 Dec.	D	Lanai	Dolphin	14-16	15-20	0-35
			Sea chub, *Kyphosus cinerascens*	50-100		N.s.[1]
			Scrawled filefish, *Aluterus scriptus*	2	1	N.s.
1978						
30 May	D	Lanai	Yellowfin tuna	800-1,000	6-8	0->50
			Dolphin	10-12	10-15	0->35
			Rainbow runner	15-20	<1	0->35
			Rough triggerfish, *Canthidermis maculatus*	80		N.s.
			Porpoises	12		
27 July	F	Kona	Skipjack tuna	200-300	2-10	0->70
			Yellowfin tuna	6		>50
			Bigeye tuna	1		
			Wahoo	3	15-20	15
			Rainbow runner	6		0-35
			Mackerel scad	>5,000		0->70
			Freckled driftfish, *Psenes cyanophrys*	50		N.s.
			Rough triggerfish	4		N.s.
			Pilotfish, *Naucrates ductor*	2		N.s.
12 Aug.	F	Kona	Skipjack tuna	Many 1,000's	2-10	0->70
			Bigeye tuna	3	20-30	>35
			Rainbow runner	12		0-70
			Mackerel scad	Many 1,000's		0-70
			Freckled driftfish	200-300		N.s.
			Rough triggerfish	12		0-35
1979						
10 Aug.	F	Kona	Wahoo	2	10-15	0-35
			Rainbow runner	4		0-35
			Mackerel scad	1,000		0-35
			Greater amberjack	5	Juvenile	N.s.
			Rough triggerfish	60		N.s.

[1]N.s. = near surface

Other Types of Fishing

The buoys off Kona also attracted many commercial skiff fishermen using the "drop-stone" method to fish for 50-200 pound yellowfin tuna usually accompanying porpoise schools. The gear is essentially a handline using 10- to 12-inch mackerel scad as bait. The hooked bait is laid on a smooth stone weighing about 2 pounds together with a package of mackerel scad chopped up and wrapped in a chum bag. Both bait and chum bag are bound to the stone by a few turns of the mainline and secured with a slipknot. The stone is lowered 30-60 fathoms and is jerked free to expose the bait and chum. Fishing was done by positioning the skiff in the path of a porpoise school and dropping the line as the school approached the skiff. The buoys enabled fishing during periods when porpoise schools were absent from the area.

One report in June 1978 indicated that up to 50 trolling and handline boats fishing at G brought in 35,000 pounds of yellowfin tuna and marlins on one weekend and that the drop-stone skiffs averaged from three to four yellowfin tuna per day.

Underwater Observation

Observations by divers were made on five occasions, twice at D and three times at F (Table 6). Dives were made generally to depths of 100 or 150 feet. Tuna schools were seen on one dive at D and two dives at F.

A yellowfin tuna school observed at D (Fig. 8), composed of 6-8 pound fish, roamed from beneath the buoy to distances of 0.5 mile or more repeatedly. Its roaming behavior may have been induced by the presence of porpoises. The school became more compact and moved about more rapidly each time a porpoise approached it.

The skipjack tuna schools observed at F behaved differently. On the first dive, 27 July 1978, groups of several hundred skipjack tuna rose to within 100 feet of the surface from below. The major skipjack tuna school was situated at depths beyond 250 feet beneath the buoy, beyond the visibility of the divers. On the second dive, 12 August 1978, many thousands of skipjack tuna were constantly in view of the divers and on several occasions, part of the school was seen to pursue baitfish (mackerel scad) to the surface within 30 feet of the buoy.

Discussion

The study provided information concerning buoy design, tuna schools attracted to fish aggregating devices, and the influence these devices had in modi-

Figure 8.—Yellowfin tuna school accompanied by porpoise beneath fish aggregating device.

fying the established fishing routine in Hawaiian waters.

Buoy Design

For the most part, the buoys, as designed, performed adequately. However, the intermittent submerging and shifting of buoy D during periods of unusually strong tidal current indicated that the design was inadequate for that particular site. To prevent similar mishaps, the buoy should be enlarged to three steel drums and the anchor weight should be increased to 2,000-3,000 pounds. Other modifications include the relocation of the anchor line attachment to the apex of the forward V section and the addition of a 40-50 pound weight to the ballast pipe to prevent the buoy from leaning over.

The importance of the drape cannot be overemphasized. Although small fish of 2-5 inches tended to remain as close to the buoy as possible, and often strayed inside of the V section, it was mainly because of the drape that large fish remained at the buoy site over prolonged periods. The reduction of fish aggregations and catches at buoys that had lost the drapes were quickly noticed by the fishermen, who clamored for immediate restoration.

The drape should be made of material that can withstand the stresses of currents and heavy wave action. The drape made of ⅝-inch polypropylene rope was effective in attracting fish, as well as being long lasting; however, the drape need not encircle the buoy, as in our experiment. Five to seven lengths of rope hung vertically and seized onto horizontal bamboo crosspieces, spaced 3-5 feet apart, and short pieces of loosened rope strands attached at intervals of 24 inches to each length of rope, should make an adequate drape.

The buoy, as designed, was adequate for trolling and pole-and-line fishing. For purse seine fishing, however, the drape should be lengthened to about 100 feet, the chain at the top of the mooring line should be 120 feet long, and the position of the weight on the mooring line should be adjusted so that the upper loop of the buoyant rope will remain at a depth of 100 fathoms or more at all times.

Tuna Aggregations Around Buoys

Distribution by Size

The fish aggregating devices attracted all sizes of tunas ranging from below 2 to over 20 pounds. Small fish below 3-4 pounds (skipjack tuna, yellowfin funa, kawakawa, and a few bigeye tuna) generally remained in the immediate vicinity of the buoys and ranged in depth from the surface to over 250 feet. Larger fish, mainly skipjack and yellowfin tunas, roamed over wider areas from 0.25 to 3 miles or more from the buoys during the day. These fish apparently returned to the buoys at night since the day's first catches by bait boats were invariably made at the buoys at daybreak. The bait boats moved away from the buoys after sunrise as they continued to fish the schools.

Medium-sized yellowfin tuna, 30-50 pounds or more, and often exceeding 100 pounds, were caught on baited lines by either deep trolling at reduced speed or by handlining while drifting. These fish were caught anywhere within 1 mile of the buoys.

Other fish such as marlin and spearfish were usually taken by trollers at distances of up to 1.5 miles from the buoys, whereas dolphin were usually taken well within 100 feet of the buoys and up to 0.5 mile away.

Multiple Schools at Buoys

It was evident from the daily catch reports by bait boats that more than one tuna school was present around a buoy at the same time. During the height of fishing activity around the buoys (April and May 1978), from two to six bait boats reported catches from the same buoy on 30 separate days. It is likely that some of the catches were made at different times of the day, but because the best fishing usually occurred at sunrise, it was not uncommon for more than one boat to be at a buoy site well before daybreak and for all of them to commence fishing at sunrise. This was corroborated by trolling boat operators who repeatedly witnessed two or more bait boats fishing simultaneously, each on separate schools spaced up to 3 miles apart.

Length of Time at Buoys

In the absence of tagging effort, it was not possible to determine how long a tuna school or individual tuna remained at a buoy site. Catches made on consecutive days at the same buoy, however, indicate roughly the length of time fish school(s) remained around a buoy and were thus available to the fishermen.

Catches on consecutive days in 1978, the year visits to the buoys were most prevalent, are shown in Table 7. Nearly all of the 2 and 3 consecutive-day

Table 7. — Tunas caught on consecutive days at buoys A, C, and D during 1978.

Month	A Consecutive days	A Visits	A Catch per day	C Consecutive days	C Visits	C Catch per day	D Consecutive days	D Visits	D Catch per day
Jan.	—	—	—	—	—	—	2	2	1,439
Feb.	2	2	1,172	—	—	—	5	7	3,252
	3	3	1,256	—	—	—	6	11	3,564
March	3	4	2,080	—	—	—	2	2	1,267
April	—	—	—	—	—	—	2	2	2,775
	—	—	—	—	—	—	2	2	3,188
	—	—	—	—	—	—	3	3	2,417
	3	7	26,016	4	5	11,201	2	3	4,160
	2	3	1,192	—	—	—	9	21	23,341
May	5	9	9,690	—	—	—	9	26	23,141
	2	3	3,813	—	—	—	2	2	2,796
	13	32	10,602	—	—	—	—	—	—
	3	5	5,378	—	—	—	—	—	—
June	2	2	6,366	—	—	—	—	—	—
	2	3	5,689	—	—	—	—	—	—
July	2	2	3,256	—	—	—	—	—	—
	2	2	1,186	—	—	—	—	—	—
	2	2	2,919	—	—	—	—	—	—
Aug.	—	—	—	—	—	—	—	—	—
Sept.	—	—	—	—	—	—	4	4	2,730
Oct.	—	—	—	—	—	—	2	2	3,657
Nov.	—	—	—	—	—	—	4	4	3,570
	—	—	—	—	—	—	5	5	2,691
	—	—	—	—	—	—	2	2	2,901
December (no visits)									

catches listed represent visits to buoys made in anticipation of good catches. Visits usually ended after a couple of days whenever the catches were less than anticipated. Longer consecutive-day catch periods of 4-6 days indicate a continuation of visits due to good catches resulting from the presence of a large school or the accumulation of schools around the buoy. This occurred twice in February at buoy D, prior to the start of the fishing season, once in May at A, after the start of the fishing season, and once in September and twice in November at D, after the end of the season. During the early part of the season, when fish schools were abundant, the period of consecutive days fished extended to 13 days at buoy A and 18 days at D.

Thus, although the length of stay of individual tuna schools at a buoy site cannot be determined from these data, the arrival and accumulation of schools around the buoys enabled the fishing boats to fish continuously for periods of up to 2 and 3 weeks at a time.

Effect of Buoy Location

Pole-and-line catches at the different buoy sites varied considerably (Table 1). Buoys A and D, which were anchored in deep water within 2 miles of the 1,000-fathom ledge were particularly successful in attracting tuna schools. They commanded 93.9 percent of all reported visits in 1978 and yielded 90.1 percent of all tunas caught around the buoys.

Buoy C, anchored off the tip of Penguin Bank and located 6 miles away from the 1,000-fathom ledge, was only moderately successful. Most of the tuna catches there were made during a span of 1 week in both January and April.

Buoy B, anchored off Penguin Bank and 15 miles shoreward of the 1,000-fathom ledge, fared poorly, as it was fished only on one occasion. Since only visits resulting in catches were reported by bait boats, it is likely that more visits may have been made to B and C, as well as to A and D. Nevertheless, both B and C received little attention from these boats since they were located too close to Penguin Bank where schools of tunas were known to appear only occasionally.

Trolling boats based at Kewalo Basin which visited A, B, and C also recorded low catches of tunas at B and C (Table 5). Verbal reports of troll fishing at the two buoys placed off Kona indicated similar results. Buoy F, which was anchored at a depth of 1,250 fathoms, attracted large concentrations of skipjack and yellowfin tunas, but buoy G, which was anchored at a depth of 220 fathoms and 3.5 miles away from the 1,000-fathom ledge, was not as successful in attracting skipjack tuna schools.

The superior catches of skipjack tuna at buoys A, D, and F were apparently due to their placement at or near the 1,000-fathom depth contour. This was not surprising since we had known through interviews with both pole-and-line and troll fishermen prior to our selecting the buoy sites that large yellowfin tuna generally followed the 1,000-fathom contour in moving north and south along the leeward coasts of the islands. We suspected that schools of skipjack tuna would follow the same pattern.

Influence on Fishing Routine

Pole-and-Line Fishing

The usual fishing routine followed by bait boats was to spend 1 day, occasionally 2, fishing for baitfish and 1 or 2 days, sometimes 3, fishing for skipjack tuna. Consequently, 30-50 percent of the time was lost to baiting operations. Additional time was lost at sea due to scouting for tuna schools.

The introduction of the buoys eased the stringent demands on the supply and condition of baitfish and eliminated scouting time and time lost in pursuing schools. Night baiting often was sufficient to provide baitfish for a day's fishing. Consequently, fishing routine was reduced to baiting at night and fishing the next day. If the catch was sufficiently large, the boats would return to port well before noon and prepare for night baiting. Following this routine, many boats were able to fish 5 or 6 days a week. One boat fished 8 days during a 9-day period. On numerous occasions vessels visited buoy A with less than the minimum amount of baitfish normally required for a day's fishing, and with baitfish in slightly weakened condition because of the short distance from port, and fishing around it required less intensive chumming.

Troll Fishing

Trolling boats also modified their daily routine. They headed directly for the buoys in the morning and again on their

way into port. Some trollers even changed their fishing method by either trolling deep with live bait at very low speed or drifting and fishing with light tackle or handlines.

Handline Fishing

In Kona, Hawaii, where handlining (drop-stone fishing) for medium to large yellowfin tuna has been going on for a number of years, the introduction of the buoys provided an additional dimension to fishing. In the past, daylight fishing for large yellowfin tuna accompanying porpoises was done by dropping lines in the midst of a school of porpoises. The porpoise schools usually passed through the area within a day or so. With the installation of the buoys, however, the porpoise schools remained in the area for many days at a time, circling the buoys at distances of 4-6 miles all day long.

A similar type of fishing called ikashibi fishing, is done off Hilo, Hawaii, where squid is used as bait, supplemented by mackerel scad (Yuen, 1979). Because live squid is used as the principal bait, fishing is done usually at night. The fishery, which began in 1973, shows promise of becoming an important segment of Hawaiian fisheries. The catch, consisting of bigeye and yellowfin tunas and, occasionally, albacore, increased from 89.0 t in 1973 to 154.6 t in 1975. This fishery could benefit from fish aggregating devices.

Buoy Benefits

It is not possible to determine precisely what the total pole-and-line catch might have been without the buoys in 1978, nor to what extent the buoys had increased the off-season catches because both monthly and year-to-year catches of the fishery fluctuate widely. There is no question, however, that the buoys were a boon to the pole-and-line fishermen, particularly with respect to more economical use of baitfish, to a reduction of time lost to baiting and searching for tuna schools, and to reduced fuel costs.

The buoy test, which was aimed primarily to aid the skipjack tuna fishery, resulted in two important side benefits. One was the heavy use of the buoys by trolling boats, the other was the utilization of the buoys by drop-stone commercial fishermen, who were able to extend the fishing of porpoise-associated tunas from one to several days and enabled fishing in the absence of porpoise schools.

Acknowledgements

We wish to thank the captain and crew of the MV *Easy Rider* and officers and crew of the NOAA ship *Townsend Cromwell* for their excellent cooperation in mooring the buoys and monitoring the fish catch data, and Shoji Teramoto, Honolulu Laboratory, for assistance in contacting tuna boat captains for information of fishing around the buoys. Special thanks go to George Parker, Kona charter boat owner, for the use of his boat to monitor and repair the buoys off Kona, Hawaii, and to Charles Spinney, Kona charter boat owner, for recovering and towing to safety a buoy that had been cut loose from its mooring.

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The Performance and Environmental Effects of a Hydraulic Clam Dredge

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Introduction

The Northeast Fisheries Center (NEFC), National Marine Fisheries Service, NOAA, has conducted annual surveys since 1965 (excluding 1968, 1973, and 1975) to establish the distribution and abundance of the surf clam, *Spisula solidissima* (Dillwyn), along the inner continental shelf from Cape Hatteras, N.C., northward to Nantucket, Mass. Hydraulic clam dredges with 0.76 m and 1.2 m (30 and 48 inch) wide blades were used during these surveys (Serchuk et al., 1979). The efficiency of these dredges and the general effect of dredging on the substrate and the macrobenthic fauna is unknown. This paper presents the results of a diver-conducted study to estimate the dredge efficiency of the NEFC's 1.2 m hydraulic clam dredge and to assess the effect of dredging on bottom substrate and fauna.

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ABSTRACT—The efficiency of a 1.2 m hydraulic clam dredge in a surf clam, Spisula solidissima *(Dillwyn), population was demonstrated by diver scientists to be sensitive to factors such as: Speed of towing, scope of tow line and water hose, and distance between cutting blade and water manifold. When these operational specifications were near optimum, the dredge removed 91 percent of the available clams; when below optimum, efficiency was 80 percent. When dredge performance was low, larger clams, which burrowed deeper into the sediment, suffered mortalities as high as 92 percent; when high, mortalities decreased to 30 percent.*

In high clam density areas (>1,000/m^2), the dredge filled with clams after approximately 10 m of towing. Once filled, the dredge action was analogous to a snowplow as it pushed and blew clams and sediment to the sides.

Initially, the dredge track was conspicuous with a smooth track shoulder, sharply angled walls, and a flat floor. The track rapidly deteriorated through slumping and biological activity until by 24 hours it appeared more like a series of shallow depressions.

Predators were more abundant inside the dredge track than outside and were divided into two categories: 1) Ones which fed on the remains of damaged clams, and 2) those which preyed on undamaged clams. The most abundant predator feeding on damaged clams was the lady crab, Ovalipes ocellatus, *which reached a density of 1,500/100 m^2. The starfish,* Asterias forbesi, *was the most abundant predator of undamaged clams, reaching a density of 30/100 m^2. After 24 hours, predator density had returned to predredging levels except for the moon snail,* Lunatia hero, *which was the only predator to increase in abundance after the 2-hour estimate.*

Study Area

The study area off Rockaway Beach, southwestern Long Island, N.Y., (Fig. 1) was selected because of the high density of surf clams reported by Franz (1976). The area was closed to commercial clamming, except for a relatively small bait fishery, in April 1974, by the U.S. Food and Drug Administration because of high levels of bacterial pollution (Verber, 1976). High densities of clams occurred at shallow water depths (10-15 m) and in substrate relatively undisturbed by dredging or other bottom-fishing operations. The area represented an ideal location for making in situ diver observations and collections. The study area is characterized by high substrate mobility (Harris, 1976) with bottom sediment consisting of fine-medium sands at depths of 0-5 m, and silty-fine sands at depths of 5-30 m (Swift et al., 1976). Bottom currents generally flow in an easterly direction parallel to the Long Island shore (Charnell and Hansen, 1974).

Materials and Methods

Dredge Performance and Efficiency

During NEFC cruise DE-77-10, 17-25 August 1977, the NOAA Ship *Delaware II* made 60 tows using NEFC's 1.2 m hydraulic clam dredge (Fig. 2), 58 to experiment with various fishing techniques for maximizing the catch of clams and minimizing clam breakage, and two 2-minute tows to estimate dredge efficiency. Scientists equipped with scuba worked from the *Delaware II* during tows numbered 1-19 and 21-59.

The following dredge settings were varied in fishing the dredge as divers visually observed: Direction and speed of towing, scope of towline, attachment point of towline to dredge, scope of the water hose, size of digging and blowback nozzles, water pressure and flow rate to water manifold, depth and angle of cutting blade, size of cutting blade hold-down springs, and distance between blade and water manifold. Because of limited vessel and diver time, dredge efficiency was not estimated during these 58 experimental tows. Scientists equipped with scuba worked from the *Delaware II* and the NOAA Ship *Rorqual* during tows number 20 and 60 (hereafter referred to as tows #1 and #2) to observe and film dredge performance, to estimate dredge efficiency, and to make observations on the effects of dredging on the bottom substrate and fauna. Table 1 presents the dredge settings during the two dredge efficiency tows.

Dredge performance was recorded on film with a Hydro-Products[1] (Model 125)

[1]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.—Dredge settings during the two dredge efficiency tows.

Setting	Tow #1	Tow #2
Speed over bottom	1½-2 knots	½-1 knots
Towline length	37 m	33 m
Water hose length	46 m	76 m
Digging nozzle (hose nipple) size	16 mm	16 mm
Blowback nozzle size	19 mm	19 mm
Blade depth	22-23 cm	22-23 cm
Blade springs	Heavy duty	Heavy duty
Distance between water manifold and blade	22 cm	91 cm
Towing time	2 minutes	2 minutes
Diesel pressure	1,400 rpm	1,400 rpm

television camera with a 250-watt thallium iodide light source by divers riding the dredge. Dredge efficiency (in terms of percent removed from track) was calculated by comparing the mean density (no./m^2) of clams within sample quadrats inside the dredge track to the mean density (no./m^2) found in samples from the undisturbed "adjacent area" outside of the track (Table 2, Fig. 3). Divers collected six samples (¼ m^2 quadrat) inside the dredge track and six samples in the undisturbed "adjacent area" on each side (north and south) of the track during the first tow, and six samples inside and five samples outside of the track on each side during the second tow. Samples were collected down to a depth of about 23 cm at approximately 10 m intervals along the 60 m track and adjacent area starting at the 5 m mark. Sampling inside the track was random between spillage areas and included clams that were buried along with ones which were discarded by the dredge (Fig. 3). Sampling in the adjacent area included only the clams that were buried.

Dredge Track, Adjacent Areas, and Windrows

Photographic records (35 mm and video tape) and visual observations were made on: 1) Distribution of clams partially or entirely uncovered, 2) substrate type, 3) dredge track configuration, 4) breakdown of the dredge path, 5) clam behavior, 6) clam mortality, and 7) predation. Divers swam along and on each side of the dredge paths documenting the above. These in situ examinations were made immediately after

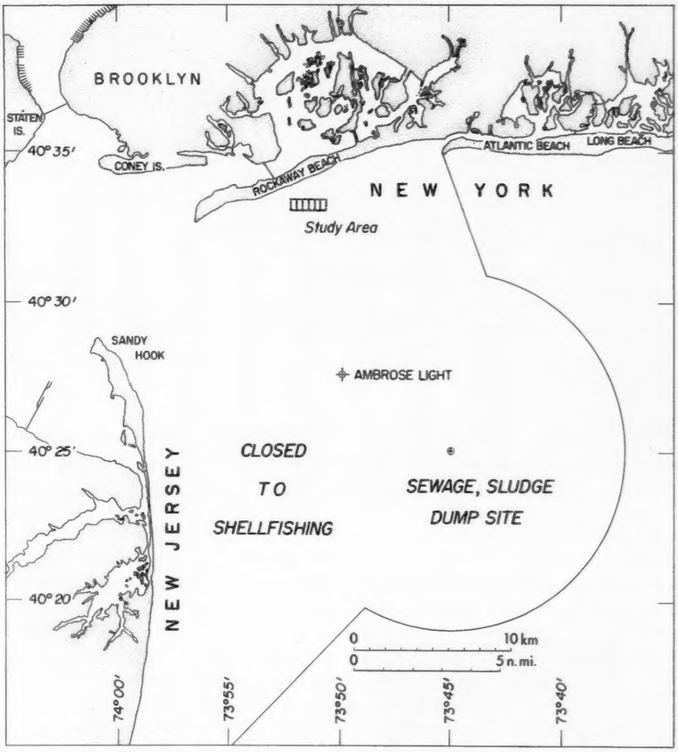

Figure 1.—Study area.

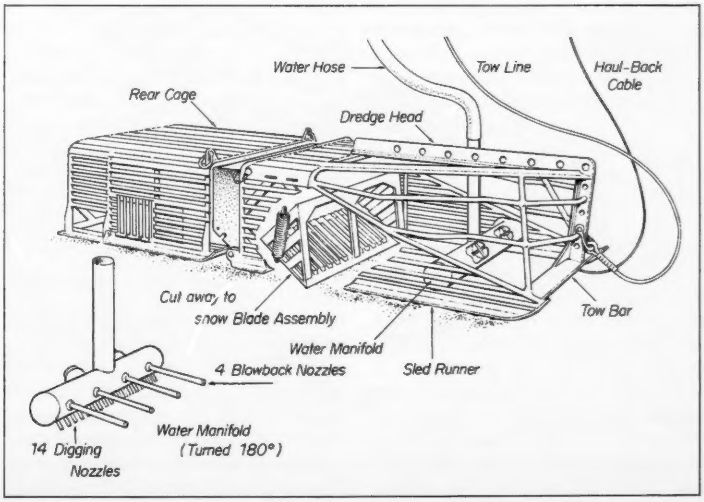

Figure 2.—1.2 m hydraulic clam dredge.

Table 2. — Diver estimates of percent removal, breakage, mean size, and density of small and large clams sampled from within and adjacent to two clam dredge tracks.

Population characteristics related to dredge efficiency and performance		Tow #1: Sample location — diver				Tow #2: Sample location — diver			
		Within path	North of path	South of path	N & S Combined	Within path	North of path	South of path	N & S Combined
Removal (%) before dredge full	Small	80	–	–	–	90	–	–	–
	Large	68	–	–	–	92	–	–	–
	All	80	–	–	–	91	–	–	–
Removal (%) after dredge full	Small	89	–	–	–	72	–	–	–
	Large	76	–	–	–	83	–	–	–
	All	88	–	–	–	73	–	–	–
Mean size (mm)	Small	29	32	31	31	31	32	32	32
	Large	107	112	113	113	112	110	111	111
Mean density (no./m^2) before dredge full	Small	258	1,312	1,368	1,320	120	1,112	1,140	1,126
	Large	12	32	42	37	4	44	56	50
	All	270	1,344	1,410	1,357	124	1,156	1,196	1,176
Mean density (no./m^2) after dredge full	Small	76	1,120	1,180	1,150	410	976	1,099	1,037
	Large	6	33	31	32	10	30	46	38
	All	82	1,153	1,211	1,182	420	1,006	1,145	1,075
Mean density (no./m^2) entire track	Small	137	1,171	1,243	1,207	293	1,003	1,107	1,055
	Large	8	33	35	34	7	33	48	40
	All	145	1,204	1,278	1,241	300	1,036	1,155	1,095
Breakage (%) before dredge full	Small	18	1	1	1	17	1	1	1
	Large	83	2	4	3	7	1	1	1
	All	21	1	2	2	14	1	1	1
Breakage (%) after dredge full	Small	26	1	1	1	28	1	1	1
	Large	92	2	4	3	30	1	1	1
	All	29	1	2	2	28	1	1	1
Breakage (%) windrow area	Small	–	2	2	2	–	2	2	2
	Large	–	35	35	35	–	20	20	20

the tow and again at 2 and 24 hours. For the first 3 hours after the tow, the beginning of the dredge path was marked by a buoy and the end by the dredge. After 3 hours, the dredge was brought aboard and a buoy was positioned in its place at the end of the path.

Treatment of Samples

The diver-collected samples were placed in 4 mm nylon mesh bags and returned to the *Rorqual.* Clams ranged in size (shell length) from 22 to 132 mm with no individuals within the 45-85 mm size range. Standard shell length measurements were made along the longest linear dimension to the nearest millimeter. A representative sample of 50 clams less than 45 mm (hereafter defined as small clams) and all clams greater than 85 mm (defined as large clams) were

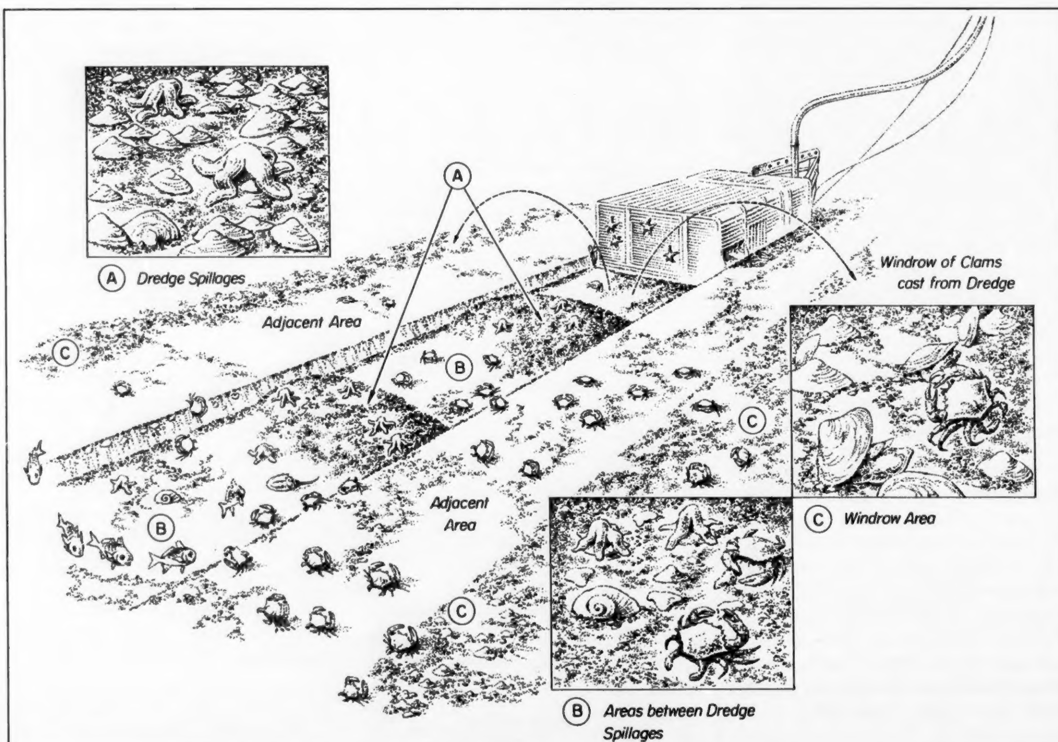

Figure 3.—Artist's rendition of a 2-hour-old clam dredge path.

measured for shell size. Diver-collected samples were divided into small and large clam categories because of the bimodal size distribution (Fig. 4) and to determine the catch efficiency of the dredge on the larger commercially valued clams. After measuring the sample, the remaining small clams were counted and added to the above totals for a measure of clam density. All damaged clams (broken shells, severed feet, and/or siphons) were counted and grouped by size category.

The dredge catch during tows #1 and #2 were hauled aboard the *Delaware II*. A representative 1-bushel sample of clams was measured and counted; the total catch was estimated by prorating the 1-bushel sample to the total number of bushels of clams in each tow. The numbers of damaged clams and other invertebrates were recorded for each sample.

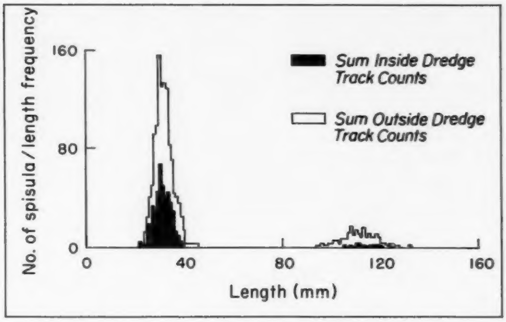

Figure 4.—Size distribution of clams in the study area.

Results and Discussion

Dredge Performance

First Tow

Tow #1 was made in a westerly direction in calm seas at a depth of 11 m. Bottom currents were negligible in the study area immediately after the tow. Underwater visibility was 2-3 m on the bottom. The dredge did not consistently dig to the same depth, but periodically "hung up" and then "surged ahead." Divers noticed that water from the digging nozzles did not penetrate the substrate as deep as the cutting blade (Fig. 2). This surging action was accentuated by the elasticity of the polypropylene towing line.

After approximately 10 m of towing, the dredge filled sufficiently to cause spillage of some clams from the rear cage onto the blade assembly during a surge (Fig. 2). They passed through the 33 mm slits between the angle stock of the blade assembly or washed under the cutting blade to form the dredge "spilling areas" inside the path (Fig. 3A). The dredge then refilled until another surge caused more spillage. These spillage areas were approximately 2-4 m apart, the full width of the deep path, and 1-3 clams thick. Hundreds of small clams were deposited at each spillage site. The blade assembly appeared to act like a strainer, selectively spilling the smaller clams.

As the rear cage became full, the filtering of water through the cage slits was restricted, creating a back pressure wave from the rear cage toward the dredge head. The pressure wave in conjunction with the normal turbulence created by the dredge moving over the bottom and the pressure exerted by the digging and blowback nozzles resulted in clams being blown out through the sides and the top of the dredge head and rear cage areas. This dredge action is analogous to a snowplow pushing and blowing everything to the sides.

Divers visually estimated that 60 percent of the discarded clams were deposited 1-2 m outside the dredge path forming a "windrow of clams" (Fig. 3C). Windrows were 1-2 m wide and extended the last 50 m of the dredge path. An estimated 2 percent of the discarded clams were deposited in the "adjacent area" with the remaining portion evenly distributed inside the dredge path between spillage areas (Fig. 3B).

Gear Changes After Tow #1

During the first tow, the blade was not cutting consistently beneath the clam bed, but periodically rode up into the bed causing considerable damage. Practice hauls (tows 21-59) made after the first diver assessment tow demonstrated that three factors affected the cutting depth: 1) Water manifold pressure, 2) distance between the water manifold and the blade, and 3) dredge nose not tending bottom. When the water pressure reaching the manifold was low, blade penetration into the substrate was too shallow. At high water manifold pressures, clams were damaged by either colliding with one another or hitting parts of the dredge before reaching the rear cage. An increase in the distance between the blade and the water manifold from 22 to 91 cm improved performance by allowing the digging nozzles a longer time to soften up the sediment in front of the advancing blade. The problem of the dredge nose lifting off the bottom was corrected by decreasing the length of the tow line from 37 to 33 m, by increasing the length of the water hose to the water manifold from 46 to 76 m, and by decreasing the towing speed from 1.5-2 knots to 0.5-1 knot; and these specifications were used for tow #2 (Table 1).

Second Tow

Tow #2 was made in a westerly direction in calm seas at a depth of 11 m. A 0.25 knot westerly bottom current was found in the study area immediately after the tow. Underwater visibility was 1-1.5 m on the bottom. The surging motion observed by divers during tow #1 was greatly reduced by the various gear changes made between assessment tows (Table 1). The decrease in surging probably contributed to a 15 percent reduction in the number of clams in the spillage area after tow #2. With these

improvements, the dredge remained hard on the bottom with the blade cutting a consistent 23 cm deep trench. After approximately 10 m of towing, the dredge filled sufficiently for windrow and spillage areas to develop. The distribution of discarded clams inside and outside the path was the same as in the first tow.

Comparisons Between Tows

The discarding of clams to form the spillage and windrow areas was probably more a function of the high clam density, which averaged from 1,095 to 1,241 clams per square meter (Table 2), than the actual dredge performance. Although few clam beds average over 1,000 clams/m^2, with longer towing time in a less dense area there is a possibility of filling a dredge. Once a dredge is brought aboard and determined to be filled, there is no way of determining at which point during the tow the dredge was full. When the dredge was fished during practice hauls (tows 21-59) in areas where clam densities were less than 100 clams per square meter, dredge spillage and windrow areas did not develop based on diver observations. The average catch during normal NEFC survey tows does not exceed 500 clams for a 4-minute tow using a 1.2 m hydraulic clam dredge (Murawski and Serchuk[2]).

Dredge Efficiency

First Tow

The percentage of small clams in the quadrat samples during tow #1 was 97.3±1.0 at a 95 percent confidence interval: A uniform distribution throughout the dredge tow area. The dredge removed an average of 80 percent of the small clams and 68 percent of the large clams in the first 10 m of the dredge track (Table 2). After approximately 10 m of towing, the dredge was full of clams and although it continued to remove clams, it immediately discarded them. The removal percentages for the remaining 50 m of the path were 89 percent for the small clams and 76 percent for the large clams. The average size of clams remaining in the dredge path after the tow was 29 mm for small and 107 mm for the large; outside the track small clams averaged 31 mm and large averaged 113 mm. Mean clam densities measured inside the dredge path after the tow were 137/m^2 for the small and 8/m^2 for the large. Densities measured outside the path were 1,207/m^2 for the small clams and 34/m^2 for the large clams.

Twenty-two bushels of clams (16,170 individuals) were caught in the dredge of which 96 percent were small clams (Table 3). The average size of the clams caught in the dredge was 24 mm for the small and 115 mm for the large.

Second Tow

The percentage of small clams in the quadrat samples during tow #2 was 96.1±0.7 at a 95 percent confidence interval: A uniform distribution throughout the dredge tow area. The dredge removed an average of 90 percent of the small clams and 92 percent of the large clams in the first 10 m of the dredge track, and 72 percent and 83 percent of the remaining 50 m. The average size of clams remaining in the dredge path was 31 mm for the small and 112 mm for the large; outside the track small clams averaged 32 mm and large ones averaged 111 mm. Mean clam densities measured inside the dredge path after the tow were 293/m^2 for the small and 7/m^2 for the large. Densities measured outside the path were 1,055/m^2 for the small and 40/m^2 for the large clams.

Again 22 bushels of clams (11,946 individuals) were caught in the dredge of which 76 percent were small clams (Table 3). The average size of the clams caught in the dredge was 29 mm for the small and 108 mm for the large.

Comparisons Between Tows

Dredge efficiencies (in terms of percent removed from track) calculated before the dredge was filled showed an increase from tow #1 to tow #2: Small clams from 80 to 90 percent and large clams from 68 to 92 percent. The apparent increase in dredge efficiency during tow #2, for the first 10 m of dredge track, was probably related to improvements in the cutting blade depth previously described in the dredge performance section. Once the dredge filled, removal of small clams from tow #1 to tow #2 decreased from 88 to 73 percent and increased for large clams from 76 to 83 percent. The dredge was more efficient during the first 10 m of the second tow, and also captured more clams during the last 50 m, but these were immediately discarded. A higher number of these discarded clams landed inside the dredge path which was seen by the 82 clams/m^2 in the dredge path for the first tow compared with 420 clams/m^2 for the second tow (Table 2).

The size composition of clams retained by the dredge was 96 percent small for the first tow, and 76 percent for the second tow, a highly significant difference (χ^2=2,512; $P\{\chi^2_1>10.8\}=0.001$). The number of large clams in a bushel sample was 27 and 130 for the first and second tow, respectively (Table 3). After the gear changes made between tows, the dredge became more efficient at removing the larger clams during tow #2.

Medcof and Caddy (1971) conducted a similar gear study to observe the performance of three types of clam dredges. In their study area a uniform density of 30-40 clams/m^2 was found at depths of 7-12 m. Their commercial hydraulic clam dredge, when "skillfully controlled," was 92 percent efficient in catching ocean quahogs, *Arctica islandica* (L.), on a sandy bottom. Although the

Table 3. — Analysis of clams captured by the dredge during the two dredge-efficiency tows.

Tow	Individuals captured	Bushels collected	Percent caught: Small clams	Percent caught: Large clams	Average (mm): Small clams	Average (mm): Large clams	Percent breakage: Small clams	Percent breakage: Large clams	Percent breakage: Overall
#1	16,170	22	96	4	24	115	15	0	14
#2	11,946	22	76	24	29	108	21	18	20

[2]Murawski, S.A., and F.M. Serchuk. 1979. An assessment of offshore surf clam, *Spisula solidissima*, population off the Middle Atlantic coast of the United States. Woods Hole Lab. Ref. 79-13, 36 p.

Clam spillage area in dredge track.

clam density measured 1,095/m^2 in our study area during tow #2 in comparison with 30-40 clams/m^2 during Medcof and Caddy's study, dredge efficiencies were similar: 91-92 percent, respectively. If the dredge is fished skillfully, the clam density does not become a factor in dredge efficiency until the dredge is filled with clams.

Track Configuration and Breakdown

The path left by tow #2 was selected for examination of the track configuration and breakdown over a 24-hour period. The fine to medium sand in the study area was covered by a 75 mm thick silty layer. During the tow, the dredge created a cloud of silt 0.5-1.5 m in height. The silt settled evenly within 4 minutes of the tow. The dredge track was conspicuous with smooth and sharply angled walls and a flat floor. The dredge track was 1.2 m wide and 60 m long. Substrate penetration depth by the dredge increased gradually down to 20 cm in the first 3 m, remained relatively constant at a depth of 23 cm for the next 54 m, and then returned to 5 cm in the last 3 m. Depths up to 30 cm were measured in areas where the dredge passed over small depressions on the bottom. The walls varied in slope from 20° to 45°, depending on the amount of sediment resettlement, the amount of slumping, the strength of the alongshore transport system, and clam predator action.

During the tow, the dredge pushed sediment off to the sides, forming heaps called the track shoulder. The track shoulder was 15-35 cm wide and 5-15 cm high when measured against the undisturbed sediment outside the path. The area of slumping varied from 5 to 15 cm into the track shoulder. Many clams were found half embedded along the slope and were an aide in distinguishing the path when visibility was poor. Slumping along the walls of the path began immediately after the tow and became more apparent with time. The clams, which were half embedded in the dredge slope, soon began spilling onto the floor of the path.

In the 2-hour-old track, slumping of the walls created a more rounded depression. The walls of the path varied in slope from 15° to 35°. The track shoulder was now 10-25 cm wide and 5-10 cm high. The area of slumping now varied from 5 to 20 cm into the track shoulder. Unburied clams had a silty film on their shell surfaces.

The 24-hour-old track lacked the well-defined shoulder seen immediately after the tow and at 2 hours. The path appeared more like a series of shallow depressions with 5°-10° sloped walls. The dredge path blended in with the general bottom features and was difficult to recognize.

Mortality

Mortality, as deduced from direct observations, occurred when damage to the clam shells resulted in parts of their viscera, or other soft-bodied tissues, being exposed. Two categories of dredge-induced mortalities were observed by divers as the dredge moved through this tightly compacted area: 1) Cut clams and 2) crushed clams. Damage of either type is considered to lead to mortality.

Cut clams were found whenever the dredge blade was not penetrating the bottom to at least 20 cm. Large clams, which burrowed deeper into the sediment, suffered the greatest damage. Many of these had their foot muscle

severed. These feet were observed on or floating near the bottom within the dredge path and reached densities up to $2/m^2$. A small number of severed siphons were observed from both size categories. The majority of the crushed clams were found after the dredge had filled. Clams were crushed by passing through the blade assembly or under the blade, by coming in contact with the inside of the sled runners, or by striking parts of the dredge or other clams while being discarded. Clam mortality due to crushing was highest among the larger clams.

First Tow

After tow #1, mortalities among the clams remaining in the dredge track for the first 10 m were 18 and 83 percent for the small and large clams, respectively. After approximately 10 m of towing, the dredge had filled and mortalities appeared to increase to 26 and 92 percent. Mortalities measured outside the dredge track in the adjacent area were 1 and 3 percent for small and large clams; in the windrow areas 2 and 35 percent for small and large clams. Divers visually estimated that 5 percent of all small clams in the spillage areas were damaged. The remaining damaged small clams were found evenly distributed inside the dredge track and outside the track in the windrow areas (Fig. 3). Divers estimated that 60 percent of all large damaged clams were found near the sides of the trench or on the slope. The remaining individuals were evenly distributed inside the dredge track between spillage areas and outside the track in the windrow areas. Divers estimated that 60 percent of all damaged clams were crushed and 40 percent were cut.

In the 1-bushel sample from the dredge catch, 15 percent of the small clams were damaged. Of the nine large clams measured, all were undamaged.

Second Tow

After the second tow, mortalities among the clams remaining in the dredge track for the first 10 m were 17 and 7 percent for small and large clams, and increased to 28 and 30 percent for the remaining 50 m. Mortalities measured outside the dredge track in the adjacent area were 1 percent for the small and large clams; in the windrow areas 2 and 20 percent for small and large clams. Clam mortality in the spillage areas and distribution of clams inside and outside the path in the windrow areas were the same as in the first tow. Divers visually estimated that 85 percent of all damaged clams were crushed, and 15 percent were cut.

In the 1-bushel sample from the dredge catch, 21 percent of the small clams and 18 percent of the large clams were damaged.

Comparisons Between Tows

Clam mortalities among the small clams remaining in the dredge track for the first 10 m were 18 and 17 percent for the first and second tows, respectively, 83 and 7 percent for the large clams. After 10 m of towing, the dredge had filled and small clam mortality increased to an estimated 26 and 28 percent, and 92 and 30 percent for the large clams. Dredge induced mortalities outside the dredge track in the adjacent area for both size categories remained less than 2 percent, while in the windrow areas small clam mortality remained approximately 2 percent and large clams demonstrated an apparent decrease of 35-20 percent (Table 2).

The most significant improvement between tows was the substantial decrease in large clam mortality throughout the dredge path. This decrease was a result of improvements in cutting blade depth which led to a reduction in the amount of cut clams from 40 to 15 percent from the first to second tow.

Medcof and Caddy (1971) found that their dredge broke the shells of more than 80 percent of the uncaught clams, but less than 20 percent of those caught; however, shell length measurements and the number of tows were not presented. For comparison purposes, mortalities from our second tow were used since the dredge efficiencies were similar. Before the dredge was full, our dredge broke the shells of 14 percent of the uncaught clams in the dredge path; windrows had not developed yet. Mortality increased to 28 percent for the clams in the dredge path after the dredge was filled. In addition, 2 percent of the small clams and 20 percent of the large clams discarded outside the path were damaged. Mortality to the clams caught by the dredge during tow #2 was 20 percent, the same as found by Medcof and Caddy (1971). Fishing mortality, as defined by Medcof and Caddy (1971), was the average number of broken clams per square meter divided by the average density of clams per square meter. The breakage to clams caught by the dredge was not included in this percentage. Medcof and Caddy (1971) found their fishing mortality to be about 10 percent. During our second tow, fishing mortality was 2 percent before the dredge was filled and about 12 percent after it was filled.

Clam Behavior

In this dense clam population, large clams were found living at a depth (measured to uppermost posterior end) of 10-12 cm below the sediment water interface with their siphons projecting between the small clams burrowed to a depth of 2-4 cm.

During and after both tows, the behavior of discarded undamaged clams was observed. In the first 2 hours after the tow, discarded small clams were more vulnerable to predators than the large clams. Some reburrowed immediately, but others remained immobile, apparently suffering from some form of dredge induced shock which lasted from 1 to 24 hours. Divers estimated that 99 percent of all clams in the dredge spillage areas were small. They were piled 1-3 clams thick and those on the upper layer were using their "leaping escape" response, previously described by Ropes and Merrill (1973), to propel themselves from the clam piles. Once they were clear, the average reburrowing time was approximately 1.5-2 minutes. The large clams had the most difficulty reburrowing; many remained on their sides and were being covered over by a silty film; some were extending their foot in an attempt to right themselves, but because of their large size could not apparently get enough leverage. Some of the larger clams may have suffered internal damage, i.e., foot severed, hinge dislocation, or damage to adductor muscles, making reburrowing impossible.

Dredge induced shock to the larger clams was noted in a few cases. For example, one large apparently undamaged clam was found upside down with its foot extended up into the water column.

In the 2-hour-old dredge path, approximately 80 percent of the undamaged small clams located in the dredge path between spillages and in the windrow areas had reburrowed (Fig. 3B, C). Small clams visually counted in the dredge spillage areas numbered approximately 150 individuals, about one-fourth of their initial population level. An estimated 20 percent of all large undamaged clams in the study area had reburrowed.

In the 24-hour-old dredge path, approximately 95 percent of all small undamaged clams in the study area had reburrowed. Small clams in the dredge spillage areas now numbered 50 individuals. An estimated 80 percent of all large undamaged clams in the study area had either been consumed by predators or had reburrowed. The few that remained were covered by a thin layer of sediment.

Predators

Predation was another form of clam mortality. Predators were more abundant inside the dredge track than outside and were divided into two categories: 1) ones which fed on the remains of damaged clams (i.e., lady crab, *Ovalipes ocellatus* (Herbst); rock crab, *Cancer irroratus* (Say); and spot, *Leiostomus xanthurus* (Lacépède)) and 2) those which preyed on undamaged clams (i.e., starfish, *Asterias forbesi* (Desor); horseshoe crab, *Limulus polyphemus* (L.); and moon snail, *Lunatia heros* (Say)). During the 2 hours after the tows, the abundance of predators feeding on clams damaged by the dredge increased sharply. These were the most mobile of the predators. Lady crabs were the most conspicuous, numbering 100/100 m^2 immediately after the tow, and 1,500/100 m^2 2 hours later (Table 4). Lady crabs were observed ripping and tearing at the exposed clam flesh and severed clam feet and siphons. On numerous occasions, divers observed interspecific competition for the available food. The rock crab density was constant at 2/100 m^2 throughout the 24-hour study period. Spot initially numbered about 15/100 m^2 and were observed in a small school of about 15 individuals nibbling on small pieces of clam flesh. Two hours later, spot abundance increased to 300/100 m^2 and a large school of 100 individuals was seen.

Predators of undamaged clams were slower to move into the study area. Starfish were the only predators observed to be preying on undamaged clams during the first 2 hours. They avoided, for the most part, the damaged clams and tended to concentrate on clams in the 25-45 mm size range, depending on the size of the starfish. Starfish initially numbered 10/100 m^2, but increased to 30/100 m^2 within 2 hours after the tow. They were found climbing up the sides and rear of the dredge full of clams resting at the end of the track. After 2 hours, moon snails and horseshoe crabs had moved into the study area, reaching abundance levels of about 4/100 m^2. They seemed to prefer feeding on small undamaged clams. Franz (1977) reported that moon snails favored clams less than 80 mm in shell length. In the diver collected samples, 7 small clams were found bored by moon snails during the first tow, and 11 during the second tow.

After 24 hours, the distribution and abundance of predators and discarded clams appeared to have returned to normal except for the broken and whole clam shells void of meat spread throughout the study area. The abundance of predators feeding on damaged clams had either returned to the predredging levels, as in the lady crab, or the predator was not observed, as in the spot. All available food from the damaged clams had been consumed. The abundance of predators feeding on undamaged clams showed that the starfish population had returned to the predredging levels, horseshoe crab population had decreased from 4 to 2/100 m^2, and the moon snail abundance had increased from 4 to 6/100 m^2. The moon snail was the only predator to increase in abundance after the 2-hour estimates.

Table 4.—Estimated abundance of predators by divers.

Predator	Initially	2 hours	24 hours
Lady crab	100/100m^2	1,500/100m^2	100/100m^2
Rock crab	2/100m^2	2/100m^2	2/100m^2
Spot	15/100m^2	300m^2	N.o.[1]
Starfish	10/100m^2	30/100m^2	10/100m^2
Moon snail	N.o.	4/100m^2	6/100m^2
Horseshoe crab	N.o.	4/100m^2	2/100m^2

[1]N.o. = none observed.

In general, approximately 3 percent of the undamaged clams discarded by the dredge during both tows suffered predator-induced mortalities.

Predators captured by the dredge were 10 lady crabs, 26 starfish, and 1 horseshoe crab for the first tow, and 33 lady crabs, 22 starfish, and 1 moon snail for the second tow.

Summary

Dredge efficiency was demonstrated to be sensitive to factors such as: Speed of towing, scope of towline and water hose, and distance between cutting blade and water manifold. When these operational specifications were near optimum, the dredge removed 91 percent of the available clams; when below optimum, efficiency was 80 percent. When dredge performance was low, the larger clams, which burrowed deeper into the sediment, suffered mortalities as high as 92 percent; when high, mortalities decreased to 30 percent.

Because of the high clam densities measured in the study area (1,095-1,240 clams/m^2 for a 2 minute tow), the dredge filled with clams after approximately 10 m of towing. Once filled, the dredge action was analogous to a "snowplow" as it pushed and blew clams and sediment to the sides. During this process, the majority of the clam mortality occurred. Although few clam beds average over 1,000 clams/m^2, with longer towing time in a less dense area there is a possibility of filling a dredge. Once a dredge is brought aboard and determined to be filled, there is no way of determining at which point during the two the dredge was full.

Initially, the dredged track was conspicuous with a smooth track shoulder, sharply angled walls, and a flat floor. The track rapidly deteriorated through slumping and biological activity until by 24 hours it lacked the well-defined shoulder and appeared more like a series of shallow depressions. Divers found that the dredge track blended in with

general bottom features and was difficult to recognize.

Predators were more abundant inside the dredge track than outside and were divided into two categories: 1) Ones which fed on the remains of damaged clams and 2) those which preyed on undamaged clams. The most abundant predator feeding on damaged clams was the lady crab which reached a density of 1,500/100 m^2. After 24 hours, predator densities had returned to predredging levels except for the moon snail which was the only predator to increase in abundance after the 2-hour estimate.

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A Comparison of Rearing Costs and Returns of Selected Herbivorous, Omnivorous, and Carnivorous Aquatic Species

YUNG C. SHANG

Introduction

It has been said that the cost of culturing staple aquatic herbivorous species (i.e., tilapia, milkfish, carp, etc.) is less than that of culturing more costly carnivorous and omnivorous species (i.e., shrimp, prawn, eel, trout, etc.) because of the savings in feed costs (Bardach et al., 1972; Korringa, 1976). Thus, a nation may encourage the culture of staple aquatic herbivores if its national development policy priority is to augment the low-cost animal protein component in the people's diet.

Also, it is often mentioned that the production of carnivorous and omnivorous aquatic species may generate a higher rate of return than herbivorous species (personal communications with some fishery officials). Therefore, some nations may choose to encourage the culture of such high-value species for export to generate greater returns and provide rural employment.

This paper examines the extent to which protein from selected aquatic herbivorous species is less costly to produce than from aquatic carnivorous and omnivorous species. It will also attempt to answer the question of whether the culture of high market value species leads to a higher rate of return.

Costs of Production

Information on costs of production of selected herbivorous, carnivorous, and/or omnivorous species is available for analysis from Mexico (FAO, 1978) and Taiwan (Taiwan Fisheries Bureau, 1979); the herbivores are tilapia, *Tilapia aurea*, and oyster, *Ostrea corteziensis*, in Mexico, and milkfish, *Chanos chanos*, and oyster, *Crassostrea gigas*, in Taiwan, while the carnivores and omnivores are freshwater prawn, *Macrobrachium rosenbergii*, and marine shrimp (Penaeids) in Mexico, and eel, *Anguilla japonica*, in Taiwan.

Comparing the cost of production per unit of gross weight among species is not relevant in selecting species for culture as a protein source because edible portions and protein content may vary significantly. For example, the refuse (or inedible) portion varies from 31 percent for marine shrimp and milkfish to 85 percent for oysters. Also, protein content varies from 8.3 g per 100 g of edible weight for oysters to 20.6 g for milkfish (Table 1).

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A more meaningful measure would be the cost of production per unit of protein produced, comparing data from the same country and for the same time period. To do that, the unit cost of production, in gross weight, for each species mentioned above is calculated first (Table 1). These calculated costs of production are then adjusted to an edible weight basis and finally they are calculated on a protein basis (1,000 g wet weight).

In terms of gross weight, the unit costs of production of oyster and freshwater prawn are less than those of tilapia and marine shrimp, respectively, in Mexico. However, these values are reversed when costs are compared on a protein basis (Table 1). This is also true for oyster and milkfish in Taiwan. Herbivores cost much less to produce than carnivores and omnivores in terms of protein in both countries, i.e., the cost of producing freshwater prawns in Mexico is more than five times that of tilapia and about three times that of oysters. In Taiwan, the cost of producing eels is more than five times that of milkfish and three times that of oysters. In terms of cost of feed and/or fertilizer per unit of protein produced, again, it costs much less to rear herbivores than carnivores and omnivores. Species in the latter group need high protein feeds which are expensive. As for oysters, no feed costs are involved because they feed directly on algae or phytoplankton.

Actually, herbivores can be cultured in a pond in low density relying on natu-

Table 1. — Estimated costs of production per unit of protein of selected species in Mexico and Taiwan.

Species	Cost/kg[1]	Refuse[2] portion	Protein in[2] edible portion per g	Cost/1,000 g[3] of protein	Cost of feed/[4] fertilizer per 1,000 g protein
			Mexico		
Oyster	$0.17	85%	0.083	$13.65	$ 0
Tilapia	0.60	62	0.188	8.40	3.72
Freshwater prawn (*M. rosenbergii*)	2.92	60	0.160	45.63	9.03
Marine shrimp (Penaeids)	3.33	31	0.160	30.16	9.45
			Taiwan		
Oyster	1.03 (meat)	0	0.083	12.53	0
Milkfish	1.04	31	0.206	7.32	1.94
Eel	4.15	33	0.168	36.87	14.93

[1]Derived from Table 2.
[2]Sources: NIH, 1972, and Anonymous, 1964.
[3][Cost of production per kg − (1,000 g × edible portion × protein in edible portion per g)] × 1,000.
[4][Cost of feed and fertilizer per kg − (1,000 g × edible portion × protein in edible portion per g)] × 1,000.

ral food present in the water, or in high density with fertilization and/or supplemental feeding. Excepting the oyster, all of the herbivores mentioned are under intensive cultivation, with fertilization and supplemental feeding. The total cost of fertilizer and supplemental feed of rearing herbivores is usually less than the cost of feed for carnivores. Also, unit costs of rearing these staple species with fertilization and supplemental feeding are usually less than without because of the proportionately higher level of production per unit of pond. However, a steep increase in the prices of fertilizer and feed could change this situation.

Table 2. — Average production costs and returns of selected species in Mexico and Taiwan.

	Mexico				Taiwan		
Item	Oyster (per raft)	Prawn (per ha)	Shrimp (per ha)	Tilapia (per ha)	Oyster (per ha)	Eel (per ha)	Milkfish (per ha)
Revenue	$2,286	$17,333	$5,084	$2,347	$5,756	$55,991	$2,833
Production (kg)	6,428	3,000	800	3,520	[1]3,600	10,800	2,300
Operating cost	$1,113	$ 8,754	$2,668	$2,110	$3,727	$44,851	$2,390
Seed		933	28	136	694	17,369	788
Feed		1,733	811	939		[3]18,158	[3]636
Fertilizer			24				
Medicine						799	26
Labor	239	1,600	640	124	1,590	2,704	355
Fuel and Oil	65		15				
Lease		107	107	107		131	79
Electricity			171			1,869	24
Interest	307	2,293	582	540	47	1,162	29
Maintenance		444			983	717	74
Depreciation	458	1,200	206	175	284	1,277	32
Miscellaneous	44	444	84	89	129	665	347
Profit	$1,173	$8,579	$2,416	$ 237	$2,029	$11,140	$ 443
Average rate of return on operating cost (%)[2]	105	98	91	11	54	25	19

[1]Meat.
[2]The rate of return on initial investment is not calculated due to the limited data available on capital costs in Taiwan.
[3]Total for feed and fertilizer.

Sources: FAO (1978), and Taiwan Fisheries Bureau, 1979.

Rate of Returns

From the producer's point of view, the cost of production of carnivorous and omnivorous species is higher than that of staple herbivorous species both in physical terms and in terms of protein. However, the output price is also relatively high for the former. Whether the production of high-priced species yields more profit than staple species, depends upon the relative cost of production per unit of output and the relative farm price of output. In Mexico, the estimated annual rate of return on operating cost averages about 105 percent for oyster (raft culture), 98 percent for freshwater prawn, 91 percent for marine shrimp, and 11.2 percent for tilapia (Table 2). In Taiwan, the average rate of return on operating cost is on the order of 55 percent for oyster, 25 percent for eel, and 19 percent for milkfish.

Though oyster is not the least costly species to produce in terms of protein, it yields the highest rate of return (on operating cost) among other species in both countries. On the other hand, tilapia in Mexico and milkfish in Taiwan are the least costly species to produce in terms of protein but yield the lowest rate of return from a producer/investor point of view.

Summary and Conclusions

The quality of protein is equal between carnivores and herbivores, and the preference for one over the other is very much culture conditioned and economic oriented. If the sole objective of aquaculture development is to improve the animal protein component in the people's diet, species with low production cost in terms of protein should be considered first if it is preferred by the people and if the production of the species is economically feasible. Although the rate of return in producing these low-cost herbivores may be relatively low from a financial point of view, the social benefits derived by such a development, such as providing cheap protein food and creating employment in rural areas, may justify the public support.

Actually, production of herbivorous species may not always yield a low rate of return as exemplified by oyster culture in both countries. In addition, herbivorous species, in many cases, are good candidates for polyculture with carnivorous and/or omnivorous species to increase production and hence profit per unit of pond. This practice has been increasingly adopted in both developing and developed countries.

Production of high-value species in developing countries may also be justified, because it generates a higher rate of return, earns foreign exchange, and thereby creates employment in rural areas.

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Developing Fish Resources Can Offset U.S. Trade Deficits

Eight major fisheries resources scheduled to be developed in the U.S. 200-mile fishery conservation zone during the next 10 years could reduce the United States' annual trade deficit by $1.7 billion, according to Terry L. Leitzell, (former) NOAA assistant administrator for fisheries. Leitzell told the House subcommittee on Fisheries and Wildlife Conservation and the Environment in early June that the fisheries trade deficit currently runs $2.5 billion yearly. The subcommittee was hearing testimony on amending provisions of the Merchant Marine Act of 1936 establishing a capital construction fund that is used by the fishing industry to develop shoreside facilities.

Under the present law, U.S. merchant and fishing vessels may defer payment of Federal taxes on income set aside annually in special accounts for the future purchase of a vessel. All deferred taxes eventually are regained by offsetting reductions in the depreciation allowances for the property acquired.

"We estimate that the development of the Pacific mackerel, Atlantic mackerel, Pacific whiting, Atlantic whiting, Atlantic squid, Gulf of Mexico groundfish, Atlantic groundfish, and Hawaiian fisheries will increase domestic landings by 2.5 million metric tons a year," Leitzell said. That will bring an additional $782 million annually in vessel revenues, create more than 43,000 permanent jobs and add $1.2 billion yearly to the gross national product, he noted.

Leitzell told the lawmakers that most of the fishery resources involved in the eight major developments have been heavily fished for years by foreign nations whose fishing vessels and processing motherships come across two oceans each year to do so. He noted to the subcommittee that the Magnuson Fishery Conservation and Management Act gives the United States the ability to restrict foreign fishing operations within 200 miles of its coastlines and provides it with a mandate to develop resources currently underutilized by the domestic industry.

Hormone Research Aids Pacific Salmon Culture

Aquaculture companies engaged in commercial production of coho salmon, *Oncorhynchus kisutch*, in the Pacific Northwest see new hope for cutting their economic losses, thanks to a hormone control research project being conducted jointly by Washington Sea Grant (WSG) and the National Marine Fisheries Service (NMFS). "Companies that grow young salmon in freshwater hatcheries and then transfer them to seawater net pens or release them into the ocean have found that sometimes as many as 80-90 percent of the fish will either die or they will simply not grow after being transferred," says Walton Dickhoff, one of the researchers at the University of Washington, adding, "This is obviously a financial blow to aquaculture companies."

Workers in the WSG/NMFS project, however, have discovered that thyroid hormones play a critical role in readying the young salmon for entry into seawater. "If changes in the levels of thyroid hormones in the blood of juvenile coho salmon are measured, it is possible to predict the correct time for transferring the salmon from fresh to salt water," says Dickhoff. Knowledge of the blood concentration of thyroid hormones can reduce the economic loss that results from too early or too late transfer of the fish. This technique of hormone measurement is presently being tested by several sea-ranching companies in the Pacific Northwest and, according to Dickhoff, it looks very promising.

Another area in which the use of hormones appears fruitful concerns the artificial acceleration of spawning of adult salmon. "The supply of eggs for salmon aquaculture operations in state hatcheries is a continual problem," says Stacia Sower, another WSG researcher. "Unfortunately, when adult salmon return to freshwater hatcheries, they often do not spawn before they die." Sometimes, the early death is due to outbreaks of disease, and in other cases, the reproductive organs do not fully mature. According to Sower, research has shown that if the fish are injected with a combination of a brain hormone (luteinizing hormone-releasing hormone or LHRH) and a pituitary gland hormone (gonadotropin), the adult salmon will spawn earlier than normal and release all of their eggs before they die.

"This hormone treatment allows aquaculture companies to take a larger number of eggs and thus reduces their dependence on public hatcheries for their supply," says Dickhoff. Furthermore, obtaining eggs at an earlier date allows an earlier start for the freshwater growth of young salmon and since juveniles can be released at a larger size, a greater number of fish may return.

Mexico's Fisheries and Their Development

The Mexican Government has proclaimed self-sufficiency in food production a primary national goal, and has made sizeable investments to achieve that objective. Serious problems in the agricultural sector, however, have forced Mexico to increase its food imports.

The rapidly growing fishing industry has been one of Mexico's few successes in expanding food production for its growing population. As a result, recent Mexican administrations have assigned a high priority to fisheries development and have made substantial investments in the fishing industry.

Catch

The Mexican Government reported a 1979 fisheries catch of 875,000 metric tons (t), a 25 percent increase over the 700,000 t caught in 1978. Preliminary statistics suggest that the 1980 catch may be about 1.0 million t (Table 1). While the actual statistics have to be treated with some skepticism, it is clear that the country's massive $1.3 billion National Fishery Development Program (1977-82) has already resulted in a substantially increased catch of fish and shellfish. Mexico's important shrimp, anchovy, and tuna fisheries are all of particular interest to the United States.

Table 1.—Mexico's annual fish catch[1], 1970-80.

Year	Quantity (10^3t)	Percent change	Year	Quantity (10^3t)	Percent change
1970	351.3	+31	1976	526.3	+13
1971	399.8	+14	1977	610.8	+16
1972	426.8	+ 7	1978	702.6	+15
1973	449.1	+ 5	1979	874.9	+25
1974	401.7	−11	1980	[2]1,000.0	+14
1975	467.5	+16			

[1]Source: FAO "Yearbook of Fishery Statistics," 1979. The catch data cited in this table varies from previous reports issued by the NMFS Division of Foreign Fisheries Analysis because of revised FAO statistics which exclude seaweed production.
[2]NMFS Division of Foreign Fisheries Analysis estimate.

Shrimp

Mexican shrimp fishermen caught a record 74,000 t in 1979, a 10 percent increase over the 67,300 t caught in 1978. Fishermen reported increases along both the Pacific and Gulf coasts. The Gulf increases were surprising because of the cooperative fishermen's strike in early 1979 and the Ixtoc oil spill. Some observers speculate that the Ixtoc spill forced Mexican fishermen to shrimp in unfamiliar grounds not contaminated by the oil, where productive new shrimping grounds were discovered.

Data on the 1980 catch was not yet available, but preliminary reports suggested that it was about the same as the 1979 catch. The Gulf catch improved, but the Pacific catch declined. Mexico has a shrimp fleet of 3,000 trawlers and officials hope to have replaced about 300 of the oldest trawlers by 1982. Based on past experiences, however, it is likely that many of the older vessels will continue to remain active in the fishery.

Mexican officials claim that fishermen are currently harvesting the maximum sustainable yield of shrimp along both the Pacific and Gulf coasts. Mexican Pacific coast fishermen apparently are fully utilizing Pacific shrimp stocks. The Pacific fishery is Mexico's most important and accounts for about 60 percent of the country's total shrimp production. Fishermen based in Mazatlan, the most important Pacific shrimp port, reported an average annual shrimp catch of only 13 t per trawler during the 1979-80 season. Mexican Gulf fishermen probably do not fully utilize stocks, although there is considerable debate by officials and biologists on that subject.

The Mexican Government has attempted to assist fishermen by promoting cooperatives. Many of these cooperatives are deeply in debt and have been unable to maintain payments on Government loans. The Mexican Government cancelled some debts and refinanced other debts in 1979, but told the cooperatives that in the future they would have to manage their affairs better. Some industry observers doubt that the Government will take any drastic action against the politically powerful cooperatives, but the Government fisheries development bank (Banpesca) recently did repossess several cooperative shrimp trawlers.

Many Mexican shrimp companies and cooperatives had serious economic problems during 1980 because of the weak international market for fishery products. The U.S. economic recession and high interest rates caused U.S. shrimp prices to decline in 1980. Ocean Gardens and Crest[1], the U.S.-based marketing companies of the state-owned fishing company, Productos Pesqueros Mexicanos (PPM), decided to stop selling in the U.S. market when the prices began to decline in early 1980. When the prices continued to drop through mid-1980, Ocean Gardens and Crest found themselves with large unsold inventories. As a result, PPM could not pay the cooperatives for their shrimp. Many cooperatives had great difficulty obtaining operating capital and when their shrimp was finally sold, some observers estimate that PPM's marketing practices may have cost Mexican fishermen millions of dollars. PPM has been sharply criticized by cooperative leaders and DEPES (Department of Fisheries) Director Rafful is reportedly reviewing the role PPM plays in marketing Mexican fishery products abroad. The Mexican press reports that Banpesca will in the future provide working capital to the cooperatives instead of PPM. The

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

stronger 1981 market for shrimp, however, may reduce the pressure for further administrative changes in PPM.

Mexican officials have taken several shrimp management decisions which were expected to be implemented during 1981. A seasonal closure of the shrimp fishery was planned in the Gulf for the first time to allow juvenile shrimp to mature. From March to May the small juvenile shrimp can be caught migrating from coastal estuaries to deeper waters. DEPES hoped that restricting fishing during March, April, and May would allow fishermen to catch larger quantities of adult shrimp later in the year, thus increasing the yield of the fishery. DEPES is encouraging shrimp fishermen on both sides to fish for other species and PPM had raised prices for squid and finfish which were being caught by former shrimp fishermen. During January 1981, unconfirmed reports indicated that many Pacific coast cooperative shrimp fishermen decided to refit their trawlers for other species.

Tuna

The Mexican Government has given priority to the development of the country's tuna fishery which is now Latin America's most important. Catches of yellowfin and skipjack tuna totaled 30,600 t in 1980, a 13 percent increase over the 27,200 t caught in 1979. The NMFS Division of Foreign Fisheries Analysis anticipates a much larger catch increase in 1981 because Mexico almost doubled the fishing capacity of its fleet during 1980. Most of the new vessels were obtained by forming joint ventures with the owners of U.S. tuna seiners. Mexico plans to acquire eventually 66 tuna vessels of which 42 will be medium to large purse seiners with carrying capacities in excess of 750 t. DEPES officials originally projected a 1982 tuna catch of over 100,000 t and some observers are now anticipating a 125,000 t catch.

Most of Mexico's tuna fishery is currently conducted in the Pacific and landed at the port of Ensenada. The Pacific port of Mazatlan, however, is becoming increasingly important. The Mexican Government, through PPM, has decided to enter the tuna fishery. The PPM fleet of 18 vessels will be based in Mazatlan where the company is also building a large processing complex. The Pacific will be Mexico's primary tuna ground, but a smaller fishery in the Gulf of Mexico has also been initiated. DEPES is carrying out tuna stock assessment studies in the Gulf and some private companies have already begun the fishery there. Plans call for introducing purse seiners and bait boats as well as shrimp trawlers which have been refitted for longlining. Officials believe that yellowfin, bluefin, blackfin, and skipjack tuna can be caught in commercial quantities.

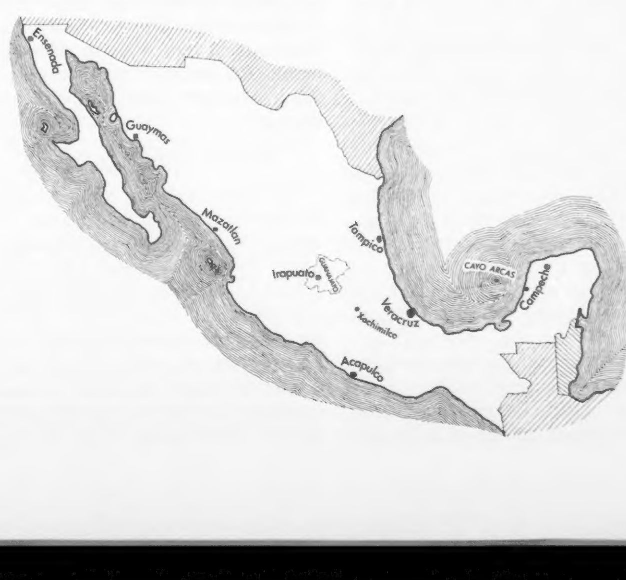
The future of Mexico's tuna fishery is unclear, however, even with the planned expansion of its fleet and processing capacity. The industry will have to solve two major problems. One, Mexico will not be able to operate its growing fleet profitably if restricted to its own 200-mile zone. Tuna is a highly migratory species and there are great annual variations in tuna abundance off specific countries. In recent years tuna has been abundant off Mexico, but this situation may not be permanent. Unless Mexico is able to negotiate access to the coastal zones of other eastern Pacific nations, the Mexican tuna industry could encounter serious difficulties during the years when tuna is not abundant off Mexico.

Two, the Mexican tuna industry has lost access to the world's major tuna market—the U.S. market. Until 1980, about half of Mexico's tuna catch was imported by U.S. canneries. The United States, however, embargoed tuna imports in 14 July 1980 because Mexico seized and fined U.S. tuna purse seiners. Since the embargo, the Mexican Government has attempted to find alternate tuna markets in Western Europe. While precise details on its efforts are not available, unconfirmed reports suggest that Mexico has not been overly successful.

The loss of the U.S. market will require Mexican companies to review their expansion plans. A larger quantity of tuna could be marketed domestically and unconfirmed reports suggest that DEPES has decided to direct more of the catch to the domestic market. Domestic sales, however, are less profitable than export sales. Reliance on the domestic market would thus affect the profit margins of Mexican tuna companies.

Anchovy

Mexican Pacific coast anchovy fishermen reported a catch of 227,000 t in 1979, a 25 percent increase over the 181,000 t caught in 1978. Data on the 1980 catch were not yet available. Most of the catch is landed in Ensenada for reduction to fish meal. Mexico's northern anchovy stock is shared with the United States, but the two countries have not coordinated their management plans. Mexico has not established any catch restrictions even though U.S. fishermen based in California are strictly regulated. Many U.S. fishermen and



biologists are concerned about the current intensive Mexican fishing effort on the anchovy stocks.

Development Program

DEPES formulated an ambitious $1.3 billion National Fisheries Development Program in 1977 whose major goal was to increase the fisheries catch to 2.4 million t by 1982. The program originally called for the construction of 8,000 vessels, but DEPES now hopes that about 13,000 new vessels will be added to the fleet by the end of 1982. Most of these vessels are small launches for artisanal fishermen, but a substantial number of larger vessels such as shrimp and finfish trawlers, tuna and anchovy seiners, snapper boats, and other fishing vessels are also being added to the fleet.

Many new vessels, especially the shrimp trawlers, are being built in Mexican shipyards, but others are imported. Fishing ports and new processing plants are being constructed all along the coast. DEPES has given considerable attention to education, and an impressive system of secondary and university education now exists for students interested in fishery careers. The program also gives considerable emphasis to aquaculture and DEPES administers aquaculture centers throughout the country where the culture of tilapia, carp, trout, and other species is promoted.

It is now clear that the ambitious 2.4 million t catch target will not be achieved by 1982. Some Congressional leaders have begun to criticize DEPES Director Fernando Rafful for the failure to meet program objectives. Rafful has had to appear before the Congressional fisheries committee twice during 1980 to answer questions about the program and respond to criticism about the growing DEPES annual budget. Even if Mexico does not achieve a 2.4 million t catch by 1982, DEPES will be able to report a significant catch increase. It is not unreasonable to anticipate a catch of about 1.3 million to 1.5 million t by 1982—an impressive achievement since it would amount to tripling the 1976 catch of only 0.5 million t.

The catch increases, however, have been primarily in small pelagic species which are used for fish meal production and in increased landings of finfish species caught incidentally by shrimp trawler fishermen. The economic viability of both fisheries is an unanswered question. Some observers believe that Mexico is currently overfishing small pelagics (especially anchovy) along its Pacific coast. While additional short-term catch increases are possible, in the long-run these stocks may not support the intensive Mexican fishing effort.

Table 2.—Mexico's fisheries catch increases projected by SAM for selected species, 1982[1]. Data in 1,000 t.

Species	Catch in 1979	SAM goal for 1982
Anchovy and sardines	294.4	400.0
Tuna	27.2	125.0
Sharks	14.6	30.0
Squid	[2]3.6	230.0
Cultured species	N/A[3]	165.0
Total	N/A	950.0

[1]Source: Mexican Department of Fisheries 1979 catch data are published in *Tecnica Pesquera*, January 1980. The 1982 goal data was reported by the U.S. Regional Fisheries Attache, U.S. Embassy, Mexico City.
[2]Excludes catch taken in U.S. Fisheries Conservation Zone.
[3]N/A = Not available.

Other observers believe that the retention and marketing of the incidental catch of the shrimp trawler fishermen is not economically viable. Production of edible commodities from the incidental catch may require Government subsidies. The Government has been subsidizing PPM's multimillion dollar losses for the past several years. PPM's operating loss in 1980, for example, was about $15 million from its existing operations. Subsidized production of edible products from the incidental catch could cause even larger deficits. The Mexican Government, however, may be willing to fund the deficit to ensure the availability of low-cost food for Mexican consumers.

Mexican Alimentary System

The fishing industry has been given an important role in the Mexican Alimentary System (SAM) which President Lopez Portillo announced in March 1980. SAM is designed to make Mexico self-sufficient in food and to improve the diet of low-income Mexicans. Government officials estimate that about 35 million Mexicans currently have substandard diets. Special attention will be given to 688 localities where the Government has determined malnutrition to be a particularly serious problem.

SAM provides for increasing investments in the fishing industry by 25 percent annually, which is much higher than originally planned in the National Fisheries Development Program. Total investments projected by SAM are over $6.9 billion for all food sectors. DEPES Director Rafful announced in August 1980 that SAM aims at significant catch increases of selected species by 1982 (Table 2). Some Mexican observers are skeptical that these goals can be met by 1982. DEPES is proceeding with the plans, however, and has signed cooperative agreements with 20 state governments to promote the fisheries production and consumption goals envisioned in SAM.

Table 3. — Mexican fishery exports[1], 1975-78, in US$ million. Data for 1979[2] and 1980 were not available.

Commodity	1975	1976	1977	1978
Edible				
Fish				
Fresh and frozen	$ 5.8	$ 7.9	$ 14.5	$ 9.6
Canned	1.1	3.0	1.1	5.3
Cured	0.3	0.3	0.3	0.5
Shellfish				
Fresh and frozen	146.4	182.6	168.8	224.3
Canned	7.0	11.4	12.3	11.0
Inedible				
Fish meal			0.2	
Fish oil	Negl.			
Total[3]	160.6	205.2	197.1	250.7

[1]Source: FAO "Yearbook of Fishery Statistics," 1978.
[2]Mexican fishery exports to the United States totaled $342 million in 1979. The Division of Foreign Fisheries Analysis estimates that total Mexican exports to all countries probably exceeded $375 million in 1979.
[3]Totals may not agree due to rounding.

Trade

The value of Mexican fishery exports has increased rapidly in recent years and amounted to $250 million in 1978, or 25 percent more than in 1977 (Table 3). Data for 1979 and 1980 are not yet available, but the NMFS Division of Foreign Fisheries Analysis believes that they will show sharp increases. (Mexico's 1979 seafood shipments to the United States alone totaled $342 million.) Mexican seafood exports are dominated by shipments of frozen shrimp, which traditionally comprise about 80 percent or more of the value of all fishery exports. In 1977, the last year for which data by country is available, shrimp exports were 90 percent of Mexico's fishery exports.

The United States is the major market

Table 4.—Mexico's trade with the United States in edible fishery products[1], 1970-79, in metric tons[2].

Year	U.S. Imports	U.S. Exports
1970	42,911	4,624
1971	45,941	4,894
1972	60,639	5,215
1973	48,326	4,842
1974	47,376	5,775
1975	48,926	4,616
1976	55,407	4,164
1977	60,879	4,630
1978	65,258	5,302
1979	55,137	6,373
1980	46,156	3,881

[1]Includes shrimp which is trucked across the border for processing in Mexico and then reexported back to the United States.
[2]Source: U.S. Department of Commerce, Bureau of the Census.

Table 5. — Mexican fishery imports[1], 1975-78, in US$ million.

Commodity	1975	1976	1977	1978
Edible				
Fish				
Fresh and frozen	$ 0.5	$ 1.3	$ 3.8	$ 7.0
Canned	0.5	0.4	0.2	1.1
Cured	3.0	0.1	0.9	1.8
Shellfish				
Fresh and frozen	0.1	0.2	0.1	0.4
Canned	0.2	0.1	0.1	0.7
Inedible				
Fish meal	13.0	9.2	5.9	18.8
Fish oil	1.1	1.2	1.0	1.0
Total[2]	18.3	12.5	12.0	30.8

[1]Source: FAO "Yearbook of Fishery Statistics," 1978.
[2]Totals may not agree due to rounding.

for Mexican fishery exports. The value of shipments has increased significantly in recent years and totaled $340 million in 1979, a 50 percent increase over the $220 million exported in 1978 (Table 3). The quantity of exports has fluctuated from a low of 43,000 t in 1970 to a high of 65,000 t in 1978 (Table 4). The most important commodity is frozen shrimp. Mexico supplied 13 percent of the value of all seafood products imported by the United States in 1979 and was the United States' second most important supplier.

Mexico would like to diversify its export markets to reduce dependence on the United States. Currently Japan is the only country besides the United States to which Mexico exports significant quantities of seafood. Mexico had hoped to increase shipments to Japan in 1980, but the weak Japanese markets for seafood made that impossible. Mexico markets from 10 to 25 percent of its seafood exports in Japan annually. Mexican officials, including DEPES Director Rafful and PPM President Jose Bellot Castro, have made several trips to Japan and Western Europe to promote fishery exports. No information on the result of these efforts is yet available.

Mexico has traditionally imported only cured fishery products (mostly dried cod) and fish meal (Table 5). Fish meal continues to be Mexico's primary fishery import commodity, even though its domestic production has increased dramatically since 1975. The Mexican Government has discouraged imports of dried cod and, since 1975, purchases of that commodity have declined sharply. Imports of frozen fish, however, have been increasing steadily and have replaced cured fish as Mexico's primary edible fishery import.

Mexico imports small quantities of fishery products from the United States. Shipments of edible products totaled $35 million in 1979, but most of that total was shrimp which was trucked across the border for processing in Mexican plants and then shipped back to the United States. Actual imports are small quantities of a wide variety of products including fresh, frozen, and canned fish and shellfish. Some U.S. exporters have expressed interest in the Mexican market, but face the very restrictive Mexican import policies[2].

Mexican Fisheries Law

Mexico's existing fisheries law was enacted in 1972. The declaration of a 200-mile EEZ in 1976, the establishment of a cabinet-level Department of Fisheries, and the rapid growth of the fishing industry has necessitated modification of the existing law. The Mexican Congress has been studying a new law since 1977, but has yet to enact the bill drafted by DEPES. Some of the more significant subjects being studied by the Congress include the cooperatives, joint ventures, and shrimp aquaculture.

Joint Ventures

The Mexican Government has restricted foreign fishing along its coast and has encouraged foreign companies to form joint fishing ventures with Mexican companies. Such ventures have been formed with French, Italian, Korean (ROK), Japanese, Spanish, and U.S. companies. The most important joint ventures have formed to catch and process tuna. One of these companies, Pescatun, established in 1980, acquired 10 tuna seiners which almost doubled the carrying capacity of the Mexican fleet. Other tuna ventures have been formed with French and Italian companies.

Japanese companies have formed several joint ventures which are harvesting a variety of species including black cod, sea urchins, and squid. Less successful have been joint ventures formed with Spanish and Korean companies to fish in the U.S. Fishery Conservation Zone (FCZ). The Mexican decision in December 1980 to terminate the Governing International Fisheries Agreement with the United States means that these companies will be denied access to U.S. fishing grounds. Several of the Mexican-Spanish joint ventures have already been dissolved, but others reportedly plan to fish experimentally for squid off the Yucatan Peninsula.

Shrimp By-Catch

Mexican shrimp fishermen currently report large incidental catches of finfish along with their shrimp catch estimated at 5-10 t of fish for every 1 t of shrimp. Most of this fish is currently being discarded at sea because they are either species unfamiliar to Mexican consumers or juveniles of species which could only be sold if harvested as adults. An estimated 0.4-0.7 million t of finfish is discarded annually, a quantity equal to about half of Mexico's total 1980 fisheries catch.

DEPES has been encouraging shrimp fishermen to retain more of their incidental finfish catch and has developed new products from these species. PPM has begun to market many of these new products. Unidentified fish fillets and a new minced-fish product, marketed as "Pepepez" (Joe fish), has been the most successful. PPM has been able to sell all of the Pepepez production (about 13 t per day) from its Xochimilco pilot plant and is currently building a larger plant at Irapuato in Guanajato state which

[2]Additional details on Mexican import regulations prepared by FAO can be obtained from Hank McAvoy, Division of Fisheries Development, NMFS, 9450 Gandy Blvd., St. Petersburg, FL 33702.

should open in 1981. PPM chose an inland site for the new plant because its location in the center of Mexico will allow easy distribution to the most heavily populated areas in the country while the plant's offal will be used for fertilizer in the agricultural state of Guanajato. If Mexico successfully utilizes even a portion of the now discarded incidental catch, it would significantly increase the quantity of low-cost fish available to Mexican consumers.

International Assistance

Mexico has received fisheries development aid from both the World Bank and the Inter-American Development Bank (IDB). The World Bank is currently considering a $35 million fisheries development loan to the Mexican state-owned bank, Nacional Financiera and a much larger loan to Banpesca, PPM, and DEPES for various projects in Central Mexico. The IDB in December 1980 approved a $80 million fishery development loan to Banpesca, PPM, and DEPES, which will provide $120 million in local funding. The $200-million project financed by this loan is earmarked for projects in southern Mexico to increase the catch of many of the species included in SAM and also includes the purchase of tuna seiners. The tuna seiners will be financed by the Banpesca funds, not by IDB funds. (Source: IFR-81/70.)

Mexican Research Vessel Needs Told

The United States conducts more marine scientific research within the claimed waters of Mexico than those of any other foreign country. Clearance requests to Mexico have averaged over 30 per year for the past few years. This research has occurred during a period when Mexico has been promoting the development of its coastal zone for both living and nonliving resources.

To protect its many interests, Mexico has developed a review procedure for all incoming clearance requests that gives each of its federal agencies the right to reject foreign research proposals, recommend changes, or attach conditions. Mexico rarely denies a clearance request, but it does expect compliance with stated requirements and conditions. Experience shows that their clearance process requires considerable time.

The U.S. Department of State has recently consolidated and updated previous guidance and recommendations on obtaining research clearances from the Mexican Government. A copy of the 5-page Department of State report and related appendices can be obtained by requesting the attachments to IFR-81/82 ("Notice to Research Vessel Operators #63") from your local NMFS Statistics and Market News Office, enclosing a large (9 × 12 inch), self-addressed envelope with $0.52 postage. (Source: IFR-81/82.)

The Peruvian Fish Meal Industry

The Peruvian Government has decided to end the state fish meal company's (PESCA PERU) 8-year monopoly on fish meal marketing. PESCA PERU has had the sole right to market and export all the fish meal and oil produced in Peru, both in its own reduction plants and in the plants of private companies. The change was opposed by the Ministry of Fisheries, but is required by the country's new constitution which prohibits all monopolies.

Private companies have been lobbying for some time to be allowed to market their own fish meal. As a result of the new decision, they will now be permitted to market their own fish meal and oil products once the government makes the necessary changes in the country's general fisheries law. Some companies are considering the establishment of an independent marketing channel, although they reportedly plan to coordinate their operations with PESCA PERU to avoid competitive bidding and other conflicts.

The Ministry of Fisheries is now studying the future of PESCA PERU. Some press reports indicate that it may be converted into a limited liability company, although the government would probably continue to hold a substantial interest in the company. The Ministry is also considering diversifying the company's operations.

PESCA PERU had a very difficult year in 1980. The Ministry of Fisheries restricted the use of the fish catch for reduction to promote the production of the more valuable edible products. As a result, PESCA PERU's fish meal production declined by 45 percent from 485,000 metric tons (t) in 1979 to only 270,000 t in 1980 (Table 1). The Ministry of Fisheries has strictly limited the catch of both anchovy and sardine. Anchovy stocks have been decimated by oceanographic changes and heavy fishing effort. The Marine Fisheries Institute (IMARPE) has recommended a ban on directed anchovy fishing which the Ministry has implemented. Sardine stocks have apparently also been overfished and IMARPE has recommended that fishing effort be reduced below 1980 levels.

The landings of both these species, which are the two major species processed by PESCA PERU, declined sharply in 1980 (Table 2). Continued restrictions on fishing in 1981 and the Ministry's policy of continuing to promote the production of edible products suggest that PESCA PERU's 1981 production will also be well below 1979 levels. (Source: IFR-81/73.)

Table 1.—PESCA PERU's production, 1978-80 (in 1,000 metric tons).

Commodity	1978	1979	1980
Fish meal	585.9	485.1	272.1
Fish oil			
Crude	118.3	101.5	39.7
Semirefined	74.5	110.0	76.1
Acid fats	5.6	8.0	6.2
Guano	30.0	29.1	26.3

Table 2.—Landings of species reduced to fish meal and oil by PESCA PERU, 1978-80 (in 1,000 t).

Species	1978	1979	1980
Anchovy	1,183.2	1,362.7	720.0
Sardine	883.4	664.8	430.7
Horse mackerel	274.0	18.0	56.6
Jack mackerel	36.3	2.2	6.5
Other	163.1	26.2	11.6
Total[1]	2,540.1	2,073.8	1,225.4

[1]Totals may not agree due to rounding.

Salmonid Broodstock, Black Cod, and Successful Fishing Piers

"Salmon Broodstock Maturation," edited by Terry Nosho and published by the University of Washington Press, Seattle, contains the proceedings of workshops conducted in that city on 20-22 May 1980 and 11 March 1981. The workshops were held owing to poor survival rates with maturing broodstock and extreme variations in gamete fertility reported by salmon farmers from Alaska to Oregon.

Sessions during the first workshop dealt with the returning broodstock, captive broodstock, factors influencing adult survival and maturation, and gamete viability and fertility. The follow-up workshop was held to monitor improvements and report research progress. Adult salmon survival and gamete viability did improve primarily owing to improvements in fish culture techniques and use of freshwater to trigger the maturation process.

The 92-page paperbound volume (WSG-WO-80-1) is available for $3.00 from Washington Sea Grant Communications, 3716 Brooklyn Avenue, N.E., Seattle, WA 98105.

"Black Cod, Boom or Bust?", also published by Washington Sea Grant, contains the proceedings of a seminar in Seattle on 27 February 1980. Edited by Charlotte Henry, the 25-page paperbound booklet addresses the location and status of black cod stocks, harvest methods, preservation and quality of the fish, and marketing. Copies of the report (WSG-WO 81-1) are available from the publisher for $1.50 each.

"Fishing Piers: Design, Operation, and Use", by Raymond M. Buckley and James M. Walton, has been published by Washington Sea Grant. The authors surveyed such facilities in Florida, Texas, and California to determine what designs and management strategies provide the greatest angler satisfaction and good catches, while still protecting the fishery resources.

Pier location and construction are extremely important, say the authors. In many cases, habitat enhancement structures under and around a pier may be needed to increase the number of fish available to anglers. Physical amenities such as comfortable benches, fish cleaning stations, weather screens, bait and tackle concessions, good parking, and convenient public transportation are also desirable.

Each pier must be managed on a site-specific basis, according to the authors, taking into account the species and abundance of both resident and migratory fish, available funds, angler needs, and the goals of the pier owner or operator. This report (WSG 81-1) will be of interest to those planning to build or operating fishing piers. It is available from the publisher for $2.50.

In addition, another report **"Commercial Fish Landings, Washington State Ports, 1971-1979"**, by Terry Nosho, Roland Tomokiyo, and Dale Ward (WSG 80-4) is available for $1.50.

Locating, Counting, and Catching Fishes

Publication of **"Echo Sounding & Sonar for Fishing,"** an FAO Fishing Manual, has been announced by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England. The manual is designed to provide essential background information on physical fundamentals and equipment technology, and on their employment under different fishing conditions. Intended primarily for fishermen, instructors, and extension workers, it should also be useful to boat owners and fishery managers.

Beginning with a chapter on sound in water and its general properties, the book then describes echo sounders and explains their components, controls, and uses. Various types of echo sounders, with their variables, are explained, with hints on choosing the most suitable type for different purposes. Other chapters discuss the components, use and function of sonar, many of the types available, and the interpretation of echograms and sonargrams.

A chapter on fishing with echo sounder and sonar explains the use of the equipment in demersal fishing, pelagic trawling, purse seining, rock and wreck fishing, fishing with light and lures, and bottom trawling with sonar. The 120-page softbound volume costs £6 plus 60p postage.

"Introduction to the Use of Sonar Systems for Estimating Fish Biomass" by J. Burczynski, FAO Fisheries Technical Paper 191, describes how a sonar system functions and how to use it for estimating fish biomass and determine the spatial distribution of fish. Chapters include The Sonar System as a Means for Fish Detection and Biomass Estimation," "Elementary Hydroacoustics," and "How to Obtain Quantitative Information on Fish by Echosounding." Appendices explain the concepts of decibel units, plane and solid angles, beam forming of a transducer, averaging by integration, and performance checks of echo integrators and echosounders. The 89-page paper-bound volume is available from Unipub, 345 Park Ave. South, New York, NY 10010 for $6.00.

"Bottom Trawls for Small-Scale Fishing," by J. C. Brabant and C. Nédélec, FAO Fisheries Technical Paper 189, contains the designs of high-opening bottom trawls which could be suitable for 50-180 horsepower small-scale fishing trawlers operating in coastal waters and large lakes. It supplies all necessary information for the construction of these trawls as well as for the preparation and adjustment of their rigging. The paperbound volume is available also from Unipub for $7.50.

Salmon Handling and Freezing Techniques

"Principles for Handling Salmon on Freezer Vessels," by Inspection Officer C. Ann Davies, is a small, 24-page, booklet published by Canada's Department of Fisheries and Oceans. It incorporates advice from Fish Inspection officers, fishermen, and technologists and is aimed at owners and operators of salmon-freezing vessels.

The author provides good, concise data on how to land top quality fish, discusses vessel sanitation and stunning, handling, bleeding, and dressing the salmon. Rigor mortis, freezing techniques, and cold storage techniques are also explained. The booklet is available from the Inspection Branch, Fisheries and Marine Service, Room 301-326 Howe Street, Vancouver, B.C., Canada, V6C 2A5.

Aquaculture Progress in Southeast Asia

The journal *Aquaculture* has published a special issue 20(3), on Southeast Asian aquaculture and devoted mostly to papers presented by recipients of grants from the International Foundation for Science, Stockholm, Sweden.

The papers are introduced with an overview of Southeast Asian aquaculture by M. N. Kutty of the Fisheries College at India's Tamil Nadu Agricultural University. Additional papers relate studies on the cage culture of the Nile tilapia, *Tilapia nilotica*; grouper, *Epinephelus salmoides*; and the marble goby, *Oxyeleotris marmorata*. Another paper relates experiences with polyculture of milkfish, *Chanos chanos*, all-male Nile tilapia, and snakehead, *Ophicephalus striatus*, in freshwater ponds.

Other papers deal with larviculture techniques and isosmotic rearing of *Macrobrachium rosenbergii*. Papers on temperature and salinity effects on survival of freshwater mullet, *Rhinomugil corsula*; stimulation of ovarian maturation by sustained hormone preparations; some aspects of the biology of Malaysian riverine cyprinids; and trace metal environmental pollution problems in mussel farming in Malaysia are also presented.

The volume, 20(3):155-304, is available from the publisher, Elsevier Scientific Publishing Company, Jan van Galenstraat 335, P.O. Box 330, 1000 AH Amsterdam, The Netherlands, for $34.25.

West African Fishery Report Is Available

A report on fishery resources, landings, catch values, trade, and development plans for countries of the CECAF (Committee for Eastern Central Atlantic Fisheries) area of West Africa has been published. The study, entitled **"A Summary Overview of Fisheries in the CECAF Region,"** (CECAF/TECH/-80/21) was authored by M. Ansa-Emmim, I. Mizuishi, and G. V. Everett, who heads the FAO Interregional Fisheries Development and Management Program (CECAF Component). CECAF is one of the FAO's regional fishery development projects primarily funded by the United Nations Development Program (UNDP).

The report provides information not usually found in other studies of West African fisheries. Numerous statistical tables covering fishery agreements, imports and exports, and fish prices in selected CECAF countries accompany the text. The CECAF countries of West Africa include Benin, Cameroon, Cape Verde, Congo, Gabon, The Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Mauritania, Morocco, Nigeria, Sao Tome and Principe, Senegal, Sierra Leone, Togo, and Zaire.

A copy of this report (cost, if any, is unknown) can be obtained by writing to: CECAF Project, 56 Avenue Pompidou, P.O. Box 154, Dakar, Senegal.

South African and Namibian Fisheries

The U.S. Consulate General in Cape Town, South Africa, has prepared a report entitled "Fishing: Total Commercial Catch, Production of Processed Fishery Products, and Consumption —1979." The report describes the pelagic and demersal fisheries of South Africa and Namibia, local fishing seasons and vessels, and the rock lobster industry in 1979. The study also includes 1979 data on catches, fish processing, and domestic consumption.

South Africa, whose 1979 catch of almost 659,000 metric tons (t) ranked 23rd in the world, is the leading fishing nation in Africa. A highly developed fishing industry, including modern processing plants, vessels, and port infrastructure, is complemented by a high demand for fish and fishery products. South Africa provides an export market for selected fishery products. In 1980, South Africa imported 765 t (worth over $3 million) of U.S. fishery products, mainly fresh and canned salmon and salmon fillets.

The complete report may be purchased for $5.00 by ordering DIB 80-11-001 "Republic of South Africa: Fishing, Total Commercial Catch, Production of Processed Fishery Products, and Consumption—1979" from: NTIS, U.S. Department of Commerce, Springfield, VA 22161.

Japan's Fisheries, 1980

The Japan Fisheries Association has prepared a 49-page report entitled **"Fisheries of Japan, 1980."** The report describes major trends in Japanese fisheries. Separate chapters are devoted to fisheries catch, processing, marketing, and financing. Two useful sections of the book describe Japanese fisheries administration and list the names and addresses of fishing companies and associations belonging to the Japan Fisheries Association.

A copy of the report can be obtained by requesting "Fisheries of Japan, 1980" from the Foreign Fisheries Analysis Division, National Marine Fisheries Service, Washington, DC 20235, and enclosing a 9 × 12 inch self-addressed envelope with $1.03 postage. A limited number of copies are available.

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Citations

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, the year and month and volume and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10-inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 100 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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